SCIENTIFIC AMERICAN SUPPLEMENT. № 1651

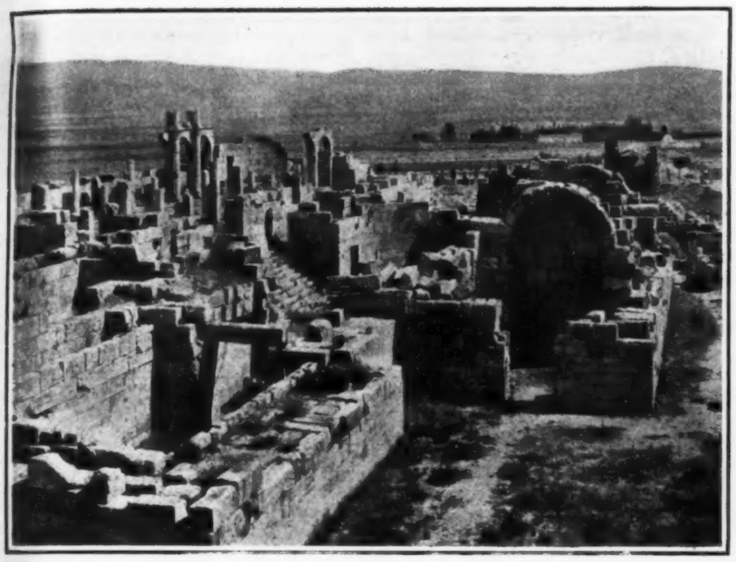
Entered at the Post Office of New York, N. Y., as Second Class Matter.

Published weekly by Munn & Co. at 361 Broadway, New York.
Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

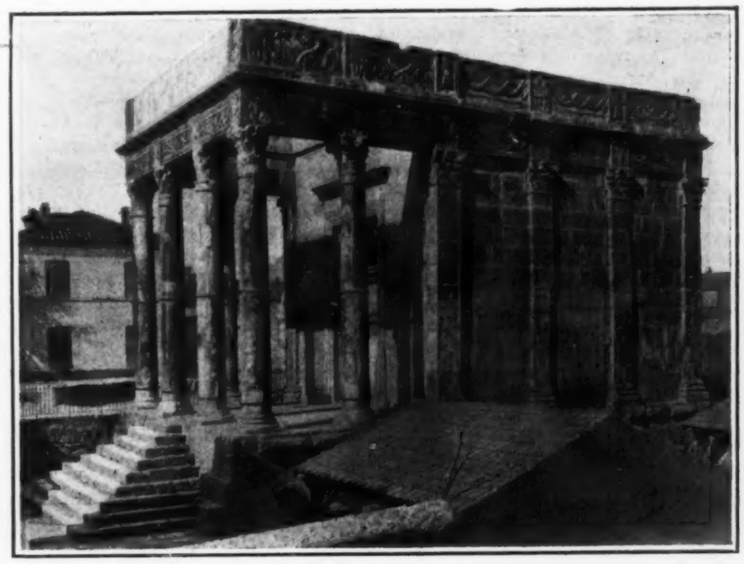
Scientific American, established 1845.
Scientific American Supplement, Vol. LXIV., No. 1651.

NEW YORK, AUGUST 24, 1907.

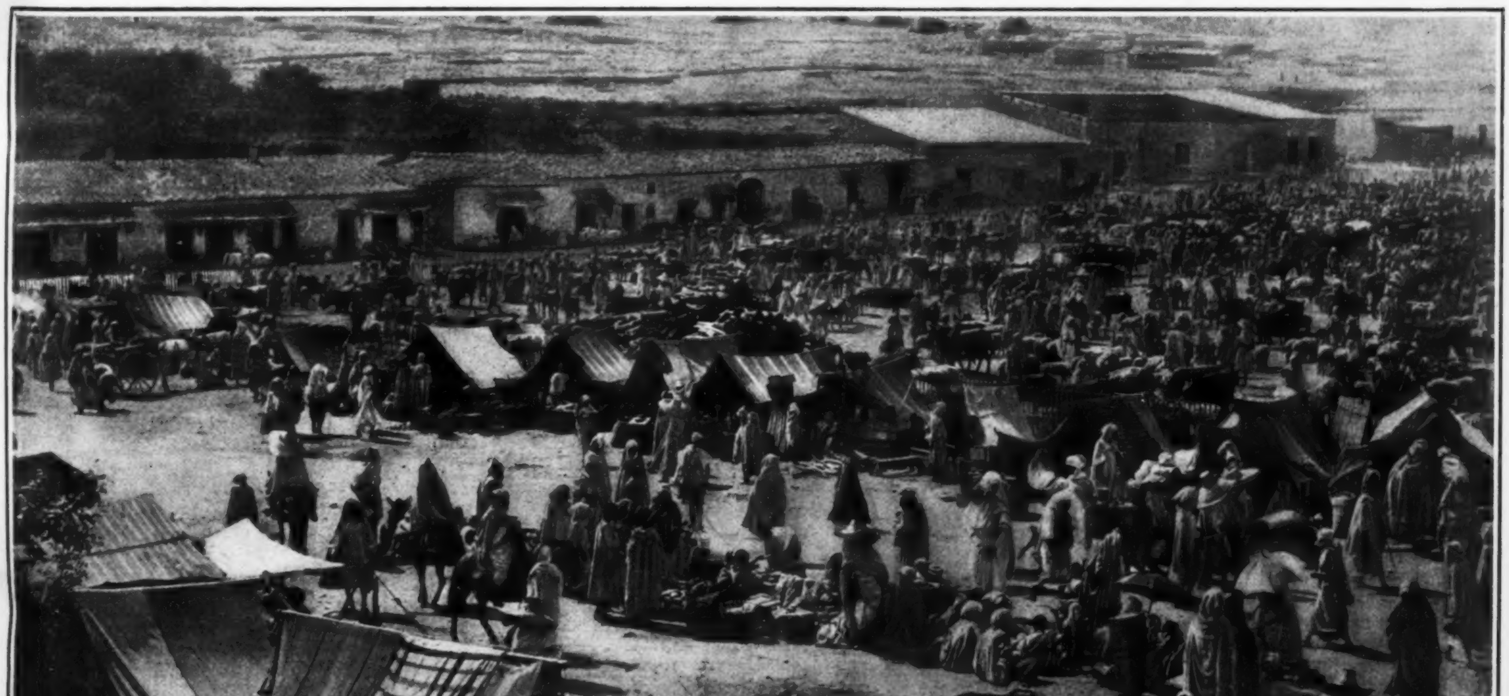
Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.



THE RUINS OF THE BYZANTINE CLOISTER AT TEBESSA.



THE TEMPLE OF MINERVA AT TEBESSA.



THE MARKET PLACE OF TEBESSA.

THE RUINS AT TEBESSA IN ALGERIA.

THE RUINS AT TEBESSA IN ALGERIA.

AN AFRICAN RELIC OF ROMAN OCCUPATION.

BY FRIEDRICH SCHMID.

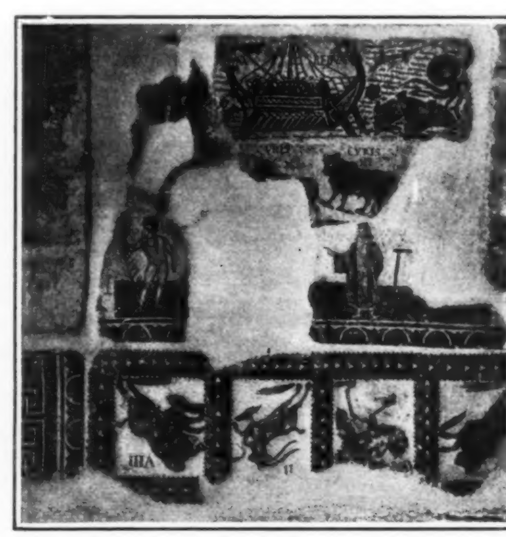
TEBESSA, though not one of the largest, is one of the most interesting towns of French Algeria. It is situated in the province of Constantine, near the Tunisian frontier, six hours or 80 miles distant by rail from the busy and rapidly growing city of Souk Ahras, the Thagaste of the Romans. On leaving Souk Ahras the railway first crosses the valley of the Medjerda, the ancient Bagradas, on several boldly constructed viaducts, and then traverses a broad, elevated and monotonous steppe region, passing near the ruins of Madoura, one of the earliest Roman colonies in Numidia (Algeria), and the birthplace of Apuleuis, the celebrated author of the fantastic satire entitled, "The Golden Ass," which contains the well-known fable of Amor and Psyche. At the station Morsot, the ruins of a Roman fortress are to be seen. The dry, barren steppe, the dreary monotony of which is broken only once, by a forest of pine and cypress, was well watered, fertile, and densely populated in Roman times. At present it is mostly pasture-land and its only important article of export is esparto grass, here known as halfa. The branch railway terminates on a plateau, elevated nearly 3,000 feet above sea level, and partly surrounded by wooded spurs of the Auris mountain range. Rich meadows and luxuriant gardens extend far on every side from the station, which is inclosed by a hedge of giant opuntias. One hundred yards from the station rise the 1,000 feet long and more than 800 feet wide. This wall is still standing and the whole modern town of Tebessa is contained within it.

About 120 years after the restoration of the city by Solomon it was taken by the Arabs in their westward march of conquest and, with the exception of the citadel, was reduced to ruins. The Arabian historians do not inform us when and by whom Tebessa was captured. According to local tradition the city was taken in the year 45 of the Hegira (665 A. D.) by the Emir Sidi Akbar Ibn Na-feh, who led the fifth army of invasion into Africa and was the first of the Moslem leaders to reach the Atlantic coast. The citadel was spared and manned by the Arabs. During the Turkish *régime* it harbored a small garrison of janizaries. Tebessa was first entered by French troops in 1842, and in 1851 General Saint Armand took formal possession of the town in the name of France. Tebessa now has about 800 French and 6,000 Arab and Kabyle inhabitants. The French administration is admirable and the city makes a very attractive appearance. The streets are paved and clean. Good water is supplied by an ancient Roman aqueduct which has been restored by the French. There are two small but good European hotels and several cafés. The wall of the Byzantine citadel, which incloses the entire modern town, is pierced by four gates: the Caracalla gate on the northeast, the Solomon gate on

A hundred yards from the arch of Caracalla stands a beautiful little temple, built in the best Corinthian style, which is sometimes called the temple of Jupiter but more commonly the temple of Minerva. The foundation, composed of three massive arches, rises 13 feet above the present level of the street, from which a flight of twenty steps leads to the quadristyle portico. The temple is about 46 feet long and 26 feet wide. It is in a good state of preservation and the beautiful ornamentation of the outer walls of the *cella* is almost uninjured. The building is now used as a museum and it contains numerous objects found among the ruins of Roman and Byzantine Tebessa, of which the most interesting are two mosaic pictures which formerly adorned the floors of two rooms in the *thermæ*, or baths, of the old Roman city. One of these mosaics, measuring 23 by 30 feet, represents the Triumph of Amphitrite. In the other a central picture, showing a galley laden with amphoræ or wine-jars, is surrounded by smaller pictures of men and animals, including bulls, boars, antelopes, and ostriches. The smaller pictures bear inscriptions and Roman numerals, and the entire mosaic was probably used in playing some of the games with which the Romans amused themselves at their baths. The collection in the temple museum contains natural as well as archæological curiosities, including the remains of prehistoric animals exhumed in the vicinity of Te-

THE TRIUMPH OF AMPHITRITE. A MOSAIC PAVEMENT FROM THE BATHS OF TEBESSA.

THE TRIUMPHAL ARCH OF CARACALLA AT TEBESSA.



FRAGMENTS OF A MOSAIC GAMING TABLE FOUND IN THE RUINS OF TEBESSA.

THE RUINS AT TEBESSA IN ALGERIA.

venerable walls of a great fortress. This is Tebessa.

Tebessa is the Theveste or Civitas Thevestinorum of the Romans. The city was founded in 71 or 72 A. D. in the reign of Vespasian and quickly rose to great importance because of its exceptionally favorable situation. It attained its greatest prosperity in the reign of Septimius Severus, who was the first African to sit on the throne of the Cæsars. He was born 146 A. D., in the ancient Sidonian city Leptis Magna in Tripoli, the ruins which are now known as Lebda, and throughout the eighteen years of his reign he gave especial favor to his native land, the Roman province of Africa. The finest of the Roman structures still standing in Tebessa were erected in his reign. The invasion of the Vandals in 429 A. D., put an end to Tebessa's first period of prosperity. It was taken and nearly destroyed, like all the other cities of the Roman provinces of Mauritania, Numidia, and Africa, with the exception of Constantine which, built on a steep cliff, remained a Roman city throughout the period of foreign dominion. One hundred and fourteen years later, and ten years after the fall of the Vandal kingdom, Tebessa was rebuilt by Solomon, the lieutenant and subsequently the successor of Belisarius. A Greek inscription made at that time and still legible on the triumphal arch of Caracalla at Tebessa informs us that: "Theveste, destroyed by the barbarians, was reconstructed from its ruins by Solomon." The new Byzantine city was much smaller than its Roman predecessor, as is proved by the extent of the ruins of each, but it was considerably larger than the modern town of Tebessa. In the southwestern quarter, Solomon erected a great citadel, of which the outer wall, built of huge blocks of stone, was 20 feet high and 6½ feet thick, was flanked by 13 square towers and inclosed a rectangle nearly

the southeast, the Constantine gate on the northwest, and the Kasba gate on the southwest. The last-mentioned gate derives its name from the Kasba, a fortress-like group of buildings erected by the French just outside the wall.

The chief objects of interest in Tebessa are two almost uninjured structures of the best period of Roman architecture: the triumphal arch of Caracalla and the temple of Minerva. The arch is a *quadrifrons* or monument with four facades. Arches of this character were erected over intersections of streets and could be traversed in four directions. With the exception of the Janus quadrifrons on the Velabrum in Rome the arch at Tebessa is the finest known monument of this sort. This masterpiece of architecture is cubical in shape and measures about 36 feet every way. Each of the four sides constitutes an independent triumphal arch and gate. Solomon incorporated the monument as a flanking tower in the wall of his citadel and filled the northwest and southeast gates with masonry. The northeast arch, on the outside of the citadel, was also partially walled up, but the southwest arch, inside of the citadel wall, was left unchanged.

The monument, according to an inscription which it bears, was commenced in 211 A. D., in the reign of Septimius Severus, and completed two years later, under his son and successor Bassianus. (Bassianus was the real name of Caracalla.) It was dedicated to the memory of the two emperors and Caracalla's mother, the Empress Julia. The beautiful ornamentation is particularly well preserved on the side toward the city. The arch is surmounted by a small superstructure, consisting of four slender columns and a roof, which probably formed a niche for a statue of Caracalla.

bessa. Among these are many of the peculiar wedge-shaped teeth of the *Carcharodon heterodon*, an extinct fish of the shark family, the discovery of which so far inland indicates that the African continent rose from the sea in a comparatively recent geological period.

An extensive area surrounding the Tebessa of today is filled with ruins of the Roman and Byzantine city, and its environing villages and country seats. There are fragments of forts, towers, cisterns, tombs, and numerous *torcularia* or oil presses, some of which are in a very good state of preservation. Doubtless many interesting relics of antiquity lie buried beneath gardens and fields, olive and carob groves, and hedges of opuntia and agave. Only one large building or group of buildings, the so-called Basilica, situated about 1,000 feet from the Caracalla gate, has been completely brought to light by Ballu, the director of the excavations in Algeria and Tunis. This was apparently a cloister erected in the fourth or fifth century on the ruins of a heathen basilica. The ruins include a high arched monumental gate and parts of a church with three naves, a baptistry and an oratory. There is also a large stable containing stone mangers pierced with holes for the attachment of halters. This stable and a bastioned wall surrounding the cloister indicate that monks could fight as well as pray, and recall the religious war, provoked by the persecution of the dissenting Donatists, that raged throughout northern Africa in the fourth century.

Tebessa is the starting point of the caravan route to Gafsa, the chief place of the salt lake region of Tunis. Railways to Gafsa and several other points are projected or already in existence. Owing to the great elevation the climate is temperate, resembling that of southern Italy. The city and the surrounding district are abundantly supplied with water by

springs, one of which yields 5,500 gallons per minute, and the land is very fertile. Good building timber is furnished by the surrounding mountains which also contain great marble quarries, which were used by the Romans. But more important than all these things are the vast phosphate beds about 10 miles north of Tebessa, which are being exploited by one French and two English companies, and yield from 150,000 to 200,000 tons annually. The rock contains from 60 to 63 per cent of phosphate of lime, which is employed chiefly in the production of artificial fertilizers and sells in France for about $11 per ton. In a few years Tebessa will have outgrown the wall of Solomon's citadel which has sheltered it for 1,300 years, but the French government, always the patron of the arts, may be relied on to preserve all valuable relics of the ancient city.—Translated for Scientific American Supplement from Illustrirte Zeitung.

PHOTODYNAMIC PHENOMENA.

LUMINOUS ANIMALS AND PLANTS.

BY PROF. H. VON TAPPEINER.

Light, which is the source of all vital energy, may also act injuriously on vegetable and animal cells, destroying lower organisms and causing inflammation of the human skin. Such effects are usually produced only when the light is very intense and very rich in violet and ultraviolet rays, or in other words, radiations of short wave length.

Within the last few years, however, means have been found to bring about similar results through the agency of comparatively weak light, namely ordinary diffused daylight. This possibility was discovered in the course of the experiments made at the pharmacological institute of Munich on the action of the alkaloids of cinchona bark and other alkaloids upon infusoria (*Paramœcium caudatum*) with reference to the treatment of malaria.

A very weak solution of acridin, one of these alkaloids, was found by O. Raab to produce exceedingly variable results. In some experiments very small doses sufficed to paralyze these very active infusoria and cause them to disintegrate in a short time, but in other experiments the weak solution of acridin had no effect whatever. As the weather happened to be very changeable, clouds and sunshine rapidly alternating, we suspected that light might have something to do with those mysterious differences in the effect, and suspicion was soon converted into certainty by special experiments. Infusoria in a solution of one part of acridin in 30,000 parts of water, in which they had lived and thrived for days in the dark, died in from 30 to 60 minutes in the diffused daylight of the laboratory, and in 5 or 6 minutes when they were exposed to direct sunlight. A much weaker solution, containing only one part of acridin in 5,000,000 parts of water, proved fatal to the infusoria in four hours in diffused daylight.

Now acridin possesses the remarkable optical property which is known as fluorescence because it was first observed in flourspar or calcium fluoride. When a solution of acridin is exposed to light some of the incident light absorbed by the solution is converted into light of a different color and radiated outward in all directions, so that the liquid appears to be self-luminous. (Similar appearances are presented by petroleum, uranium glass, and solutions of quinine.) Hence we were led to experiment with other fluorescent organic compounds, of which very many are known. Nearly all of those that we employed behaved in the manner already observed in the case of acridin. The name "photodynamic" has been given, provisionally, to these substances and their peculiar destructive action, under the influence of light. The photodynamic effect is not confined to infusoria, but extends to other low animal and vegetable organisms, including amœbæ, flagellates, bacteria, mold fungi, and yeast fungi. It is also produced in cells of higher animals in varying degrees, according to the capacity of the cell to absorb the photodynamic substance. This circumstance may be of great importance in the application of the photodynamic action to therapeutics as it suggests the possibility of operating selectively by choosing appropriate substances and regulating the intensity of the light so that parasitic or degenerated cells may be destroyed without injuring healthy tissue.

The theory, resuscitated in recent years, that attributes the vital phenomena of the cell, at least in part, to the action of substances of the nature of ferments suggested experiments on known ferments. It was found that diastase, which converts starch into sugar; invertin, which splits up cane sugar into dextrose and levulose; zymase, the effective ingredient of yeast; the albumen ferments, and the ferment of rennet lose their peculiar properties when they are mixed with small quantities of fluorescent substances and exposed to diffused daylight for a few hours. Those peculiar poisonous products of bacteria and snakes which appear to be related to ferments and are known as toxines, can be made innocuous in the same way. For example, a solution of diphtheria toxine, mixed with a 5 per cent. solution of eosin and exposed to light, had no effect on a guinea pig into which 120 times the normally fatal dose was injected.

In our investigation of the nature of photodynamic phenomena we proved, in the first place, that they are caused by those rays that are absorbed by the solution. If these rays are cut off by interposing in the path of the incident light another vessel filled with the same solution no photodynamic action takes place. Furthermore, only fluorescent substances are effective. It seemed very improbable that the effect could be due to the emitted fluorescent light as there is no essential physical difference between this and the incident light from which it is derived and, as a matter of fact, it was found that not all fluorescent substances are photodynamic and that among those which are so the effect is not proportional to the intensity of fluorescence. For example, fluorescin, a very strongly fluorescent substance, has little photodynamic power, while its near chemical relative, the dye rose bengale, of which the fluorescence is barely perceptible, is so strongly photodynamic that the effect can be detected in a solution of 1 part in 40 millions.

Hence the effect must be due to the light which remains absorbed or destroyed. We may assume, with Ledoux-Lebard, that this light causes chemical decomposition in photodynamic substances, giving rise to products which injuriously affect ferments and living cells. As a matter of fact many photodynamic dyes are not "fast" when exposed to light but, on the other hand, some which are strongly photodynamic are little affected by exposure to light. Hence it follows that there is no connection between permanence of color and photodynamic power.

We have to do with a direct effect on cells and ferments brought about by the conversion into chemical energy of part of the light absorbed by the fluorescent and photodynamic substance.

Let us now consider the relation between photodynamic phenomena and the process known in photography as color sensitizing. A plate coated with gelatine and silver bromide is very sensitive to rays of short wave length but is affected perceptibly by green, yellow, and red light only after very long exposure. In 1873 H. W. Vogel discovered that silver bromide plates impregnated with substances that absorb green, yellow, and red rays become so sensitive to light of those colors that they reproduce colored objects with nearly the same gradations of brightness that the objects present to the eye. This result appears, at first view, to be very similar to the photodynamic effect, but a more careful comparison reveals notable differences. Photographic color sensitiveness can be produced by non-fluorescent as well as by fluorescent substances, but only the latter have any photodynamic properties. This difference, however, may be only apparent, for according to G. C. Schmidt many substances which do not fluoresce when dissolved in water exhibit strong fluorescence as "solid solutions," in which form they probably exist in the gelatine-coated plate. Again, light of long wave length, even when of feeble intensity, has an appreciable though very small effect on ordinary photographic plates, but in our experiments only ultraviolet light exerted a constant and certain effect on ferments and living cells when no photodynamic substance was present. Even direct sunlight, or the concentrated light of an arc lamp, had no appreciable effect on invertin or on the ferment of rennet when the ultraviolet rays were filtered out by passing the light through glass, which is opaque to those rays. It would seem, therefore, that long waves of light cannot exert any chemical action upon cells and ferments without the intermediation of some fluorescent substance. Experiments were then made to determine the conditions under which waves of various lengths are effective, alone and in conjunction with photodynamic substances. It was found that invertin solutions in glass vessels were perceptibly weakened by long exposure to sunlight, but only in the presence of oxygen. The same condition was found to be necessary for photodynamic action. Hence it follows that the sensitiveness of invertin to other than ultraviolet rays is not created, but only increased, by the addition of photodynamic substances. With ultraviolet light the phenomena are altogether different. A solution of invertin contained in a vessel of quartz, which is transparent for ultraviolet rays, is affected strongly by exposure to sunlight even when not a trace of oxygen is present, and the effect is not increased by the addition of photodynamic substances. Hence the photodynamic effect upon invertin is an increase of its sensitiveness to light, not under all conditions, but only in the presence of oxygen. The same law probably applies to living cells, but there are limits to its generalization.

In experiments designed to test the correctness of W. Straub's theory that the photodynamic effect is due to the formation and decomposition of some strongly oxidized unstable compound which acts as a carrier of oxygen it was found that the reaction between ammonium oxalate and mercuric chloride (corrosive sublimate) under the influence of light, which Eder has recommended for use in photometry, is accelerated by the addition of fluorescent substances even in the absence of oxygen.

In regard to the practical application of photodynamic effects it should be remembered that, in the absence of photodynamic substances only radiations of very short wave length have sufficient effect on biological objects (cells and ferments) to be useful in therapeutics. It appears from the investigations of Burck, Hertel, and others that this restriction is due to the fact that the bodily tissues absorb more of the short than of the long waves. Ultraviolet rays are completely absorbed by the outermost layers of tissue and therefore they produce a very powerful but superficial effect. The longer waves of green, yellow, and red light are less rapidly absorbed and therefore penetrate to much greater depths so that their action is more diffused and less intense. But photodynamic substances, if present, absorb these long waves and so, in a measure, concentrate them and make them effective. Two advantages result from this. The costly apparatus required for the production of ultraviolet rays may be replaced by sunlight which is rich in longer waves and the effect can be produced in any part of the body, superficial or more or less internal, into which the photodynamic substance is introduced.

In the treatment of skin diseases, especially those of cancerous nature, very satisfactory results have been obtained by Jesionek at the Munich dermatological clinic. The results obtained in the treatment of lupus at Finsen's institute were less satisfactory. Both method and material differed in the two cases. Hofer's experiments with fishes at the Munich fishery experiment station were also very successful. Fishes are often injured and even killed by accumulations of certain protozoa on their skins. The parasites were destroyed and the fishes restored to health by putting a small quantity of a harmless photodynamic substance in the water.

In regard to internal effects experiments have been made with the toxines of diphtheria and tetanus, and with *Trypanosoma Brucei*, a blood parasite of the class of protozoa, which is now known to be the cause of the "sleeping sickness" and several other tropical diseases. In order to effect a cure it is necessary to inject the photodynamic substance at the same point of the animal's skin at which the *Trypanosoma* was introduced (by the bite of an insect) so that the parasite is subjected to the influence of the substance and of light immediately beneath the skin before it is able to reach the organs or the blood. This rather unsatisfactory result is due to several causes, one of which is the fact, discovered by Burck, that the albuminous constituents of the blood diminish the photodynamic effect. Further researches are required to determine the magnitude of this obstacle but their results cannot diminish the importance of photodynamic phenomena to biology and photo-chemistry.

In regard to the part played by light in the normal life of plants and animals it appears significant that chlorophyl in solution is strongly fluorescent and that fluorescent substances are widely distributed in animal organisms.—Translated for the Scientific American Supplement from Umschau.

Pickling or dipping is a preparatory process in electro-plating and effects the removal from the surface of metal objects to be coated with an electro deposit of all foreign substances by moderate heating or prolonged boiling in a soda bath. Object is thereupon corroded in acid—iron and zinc in dilute sulphuric acid (1 to 50), copper, brass, bronze, in stronger sulphuric acid (1 to 10), German silver in dilute nitric acid (1 to 10). During the pickling the objects should be repeatedly treated with the scratch brush until a clean metallic surface appears; finally rinse in clean water.

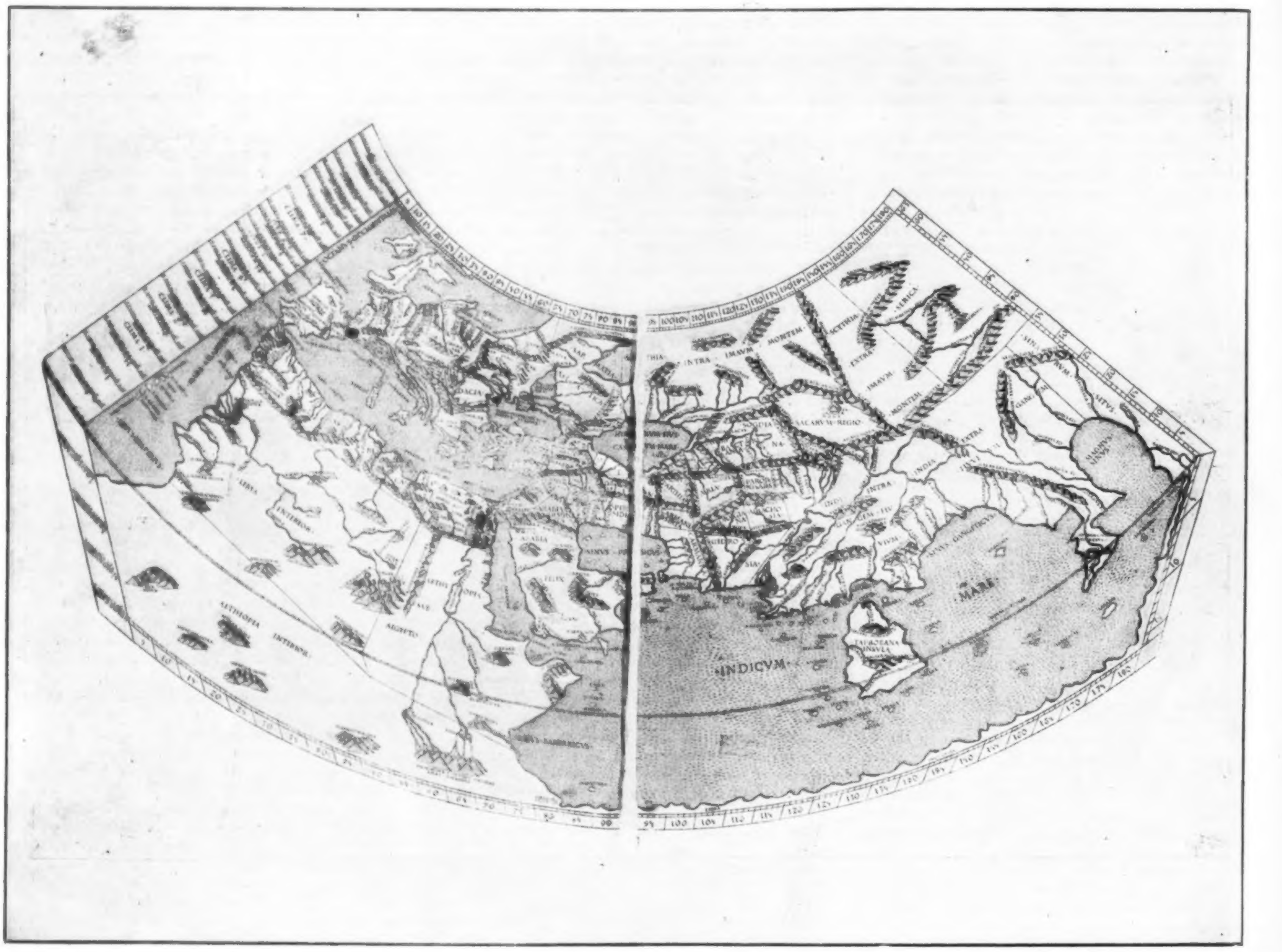
HISTORY OF MAP MAKING AND TOPOGRAPHY.*

WITH ILLUSTRATIONS OF OLD CHARTS.

BY COL. C. W. LARNED, U. S. MILITARY ACADEMY, PROFESSOR OF DRAWING.

TOPOGRAPHY is derived from the two Greek words, *τοπος*, a place, and *γραφειν*, to write. Geography comes from the words *γη*, the earth, and *γραφειν*, to write. Topography is, essentially, the art of the description of restricted areas as distinguished from those of great extent, and concerns itself largely with the expression of detail. Although topography may involve textual as well as pictorial description, it is more essentially pictorial, or graphical in the sense of the modern use of the Greek term, and aims chiefly to delineate upon a plane surface the visible features, natural and artificial, of the earth's surface in scale relations; whereas geography is so comprehensive as to involve mainly textual description, and discusses structure, features, products, political and economic conditions, and part of ethnology or the science of races.

As is pointed out by H. Stroobant in his work on topography, Herodotus describes the origin of geometry as dating from or before the surveying work of the Egyptian Pharaoh Sesostris, which work was brought about by the demands of his apportionment of land among his subjects and the necessity of readjustment after the Nile floods. In point of fact, the Pharaohs had to organize a land office, and some sort of topographic chart was its necessary adjunct. But, although of anterior origin, topography remained undeveloped until long after geography had absorbed the attention of ancient philosophers and had achieved the dignity of an exact science. Indeed, all maps of any consequence were geographic, and operations of precision connected with location were mainly astronomic in character until the eighteenth century. For centuries the only topographic maps were road maps in which there was little or no attempt to establish true relation in location. The absence of instrumental means for the accurate observation of direction or measurement rendered the construction of true topographic maps impossible. The nautical use of the polarity of the magnetic needle was not made in Europe until the twelfth century. The nautical astrolabe for determining latitude was not introduced until 1480, and longitude was determined by eclipses of the moon until about 1610, when Galileo discovered Jupiter's satellites and devised the telescope. Later came the cross and the back staff for latitude in the seventeenth century. In 1731 these were supplemented by the quadrant, and soon after by the sextant; while in 1767 was first published the Nautical Almanac, as the result of the labor of the Board of Longitude in England, for the determination of longitude and other uses. Vernier invented the vernier in 1631, and Roemer the transit in 1672. Accurate angular measurement was impracticable before the invention of the telescope with cross wires, and for want of the compass the ready and rapid knowledge of direction also was unattainable in a manner practicable for survey work, so that anything like a topographic map as now understood was out of the question before 1610, and, as a matter of fact, Picard in 1669 was probably the first to use the telescope and cross wires in connection with circular instruments for measurements; although the calculation of areas—the triangle, trapezoid, and circle—was understood as far back as 1700 B. C., as is shown by a papyrus in the British Museum. What was the character of the old Egyptian land maps we have no means of knowing, but we know from the necessities of the case what they were not. The nature of later ancient topographic maps, however, is probably well exemplified by the famous Peutingerian Table, so called after Conrad Peutinger who first made it known. This is in the Imperial Library at Vienna, and is a map of the known world in the days of Theodosius, A. D. 393. It is curiously distorted, being twenty-one feet in length by one foot in breadth from north to south, and is a sort of huge route sketch giving no sense of relation, direction, or scale. Roads, rivers, mountain ranges, and seas run, for the most part, in nearly parallel lines; while towns are shown by crude isometric drawings of houses; and Roman numerals on the roads indicate distances in Roman miles between one station and another.



MAP OF THE WORLD ACCORDING TO PTOLEMY.

(From the Geography of Cl. Ptolemy. Published in Rome in 1508.)

Topography grew out of the practical necessities of the delimitation of land to preserve ownership, and is the child of Surveying. Long before any rational conception of the shape or character of the terrestrial globe had obtained currency the measurement of land and its local delineation had resulted in the first crude topographic maps.

One of the earliest things in the nature of a map is a ground-plan of a town, probably the very ancient city of Susa at the head of the Persian Gulf, dating from the seventh or eighth century B. C. This is now in the British Museum and is very crude drawing, but shows walls, citadel and palace buildings, as well as natural features—rivers and trees. Another very old map is that of Lake Moeris in Lower Egypt, drawn on papyrus, and preserved in the Boolak Museum. Still another, of the old Nubian gold mines, shows mountains, rocks, wells, buildings and roads. Minor details, such as scattered trees, stones, and abandoned roads, are also indicated. It probably dates from the time of Rameses II., about 1500 B. C., and is the earliest specimen of map known.

There were also compiled, from time to time, itineraries, or road books, giving distances computed between a great number of places. In the year 44 B. C., Julius Cæsar instituted a survey of the Roman Empire, placing it in the hands of three surveyors who occupied twenty-five years in the task, completing it in the days of Augustus. This survey was graphically rendered in a huge map, or painting, displayed in the Portico of Agrippa. Its character can be inferred from the Peutingerian Table just described.

While topography as a science remained crude, geography, of which it is a principal branch, received the earnest attention of the ancient philosophers. Two

* Journal of the Military Service Institution.

names of great men who established it on such firm foundations that for about 1700 years their system ruled the world undisputed, stand out pre-eminent: Eratosthenes, who succeeded Euclid as the director of the Alexandrian Library about 220 B. C., and Claudius Ptolemy, a native of the same city about 150 A. D., who, upon the lines laid by his great predecessor, developed an enduring and remarkable geographic system which remained until the sixteenth century the supreme authority.

In both geographical and topographical charts the essential problem is that of relative location, and from the first the efforts of geographers were directed toward establishing fixed principles by means of which positions on the surface of the earth could be located on the sphere, and afterward, with approximate accuracy, delineated on a plane. The earliest effort to accomplish the first of these scientifically, after the sphericity of the earth was an accepted fact, was astronomical, by means of the gnomon; and Pytheas, in the days of Alexander the Great, was one of the first to make observation for latitude by its use. The gnomon consisted of an upright pillar of a known height whose shadow was cast upon a horizontal plane. By observing the change in length of this shadow from one season to another the progress of the sun from tropic to tropic could be followed; and by noting those places where, on the same day, the length of the gnomon shadows was the same, points of equal latitude on the earth's surface could be determined and a conceived the methods of projection in map making known as the orthographic and stereographic projections.

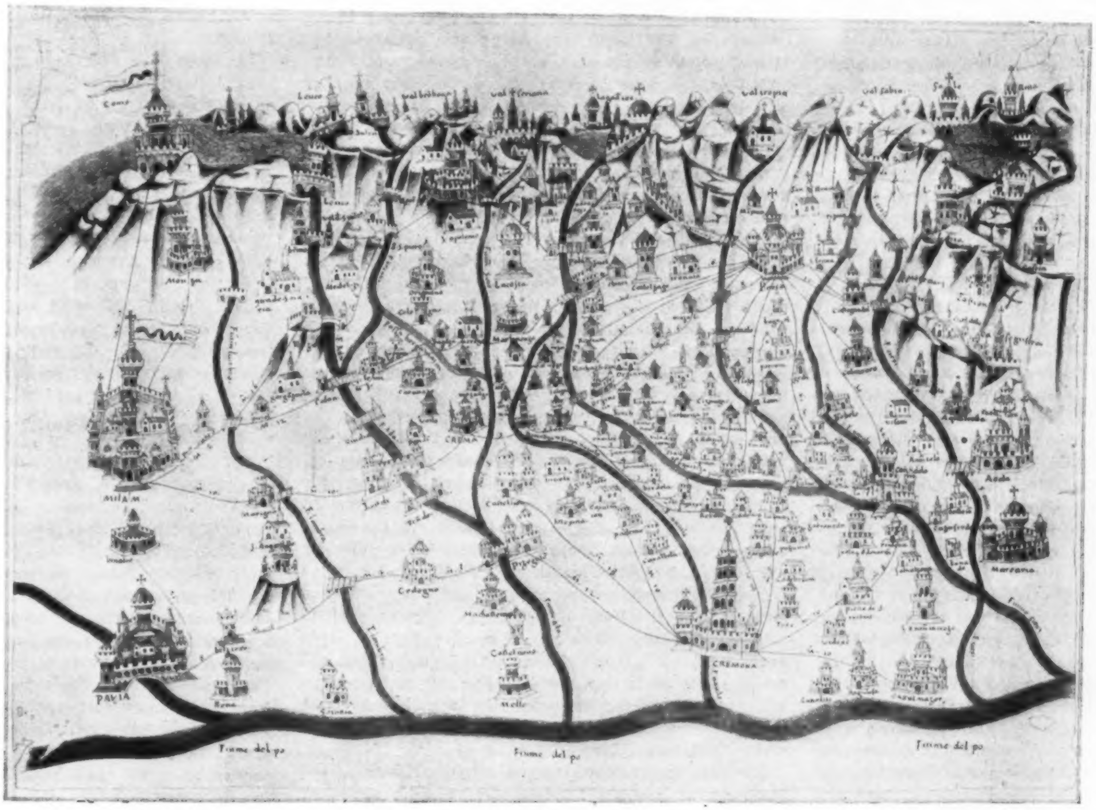
Ptolemy, having the labors of his predecessors before him, together with a vast mass of observations—such as itineraries, records of the gnomon, reports of travelers and sailors—undertook the preparation of a system of geography based upon spherical projection. Having traced upon the terrestrial sphere a system of reference lines, such as meridians and parallels, it becomes necessary for the purpose of chart or map making to devise some method of representing these lines upon a plane surface according to fixed geometrical laws. As the problem of the development of the sphere is insoluble the ingenuity of scientific geographers was exerted to invent some form of perspective projection which would afford a representation of the sphere in which distortion of form should be a minimum.

To the orthographic and stereographic projections invented by Hipparchus, Ptolemy added two more—the simple Conic and the Homeoteric—for the construction of general maps. For special maps, however, Ptolemy employed the simpler method of drawing all parallels and meridians as right lines referred to a central one of each set. The sets were drawn parallel, the inclination of the meridians being wholly neglected.

Although Ptolemy's work was accompanied by maps it is not known how far those accompanying the most of England, in 1700 proposed a projection which is a special case of the method later demonstrated by Bonne. It uses straight lines for the parallels and central meridian. On the latter are laid off the distances in degrees for the parallels, and on the parallels the distances in degrees of the intersection of the other meridians which are drawn through the points of division as curves. Lahire, in 1701, proposed the globular projection, with the eye outside of the sphere at a distance equal to $R\sqrt{½}$.

Many studies have also been made by various geographers to determine a position for the point of sight which would give the most satisfactory presentation; some by keeping the plane of projection at the center of the sphere; others by moving it toward the point of sight in order to increase the field of view so as to include more than a hemisphere.

Bonne, in 1752, modified the simple conic method by rectifying the central meridian upon a tangent cone and striking the parallels as circular arcs from the vertex through the theoretic points of division on the meridian. Each of the concentric parallels is divided as on the sphere, and the meridians are drawn as curves through the points of division. This has been extensively used in Europe for topographic maps, and was adopted by the French War Department in 1803. Lambert, in 1772, presented an original projection which preserved proportionality of areas, and in which neither the meridians nor parallels are equally divided but must be laid out by tables; the lengths of degrees,



MILITARY MAP OF THE MIDDLE AGES, REPRESENTING THE THEATER OF WAR AT THE EPOCH OF THE FIRST CONQUEST OF THE REPUBLIC OF VENICE ON THE MAINLAND.

(From British Museum.)

parallel traced. This was the method of Eratosthenes, and in this manner the latter traced through Rhodes the first parallel ever determined. Locating others through Syene and Meroe, and tracing an initial meridian through these three places, he established the earliest system of geographical co-ordinates, and made possible the present method of accurate mapping, in whole and detail, of the surface of the earth.

The next problem naturally claiming attention was the measurement of an arc of the meridian, which also was undertaken by Eratosthenes with results whose accuracy cannot be positively determined on account of ignorance of the value of the unit of measure—the Greek stadium. Eratosthenes was undoubtedly nearer the truth than his successors, Posidonius and Marinus Tyrius, whose estimates of 500 stadia to a degree were adopted by Ptolemy. Assuming for the stadium a given value of one-tenth of a mile, Eratosthenes's estimate for the circumference of the earth was approximately 25,000 miles; whereas Marinus assumed it to be 18,000 miles, which vitiated Ptolemy's entire system.

The absence of any method for determining longitude approaching in accuracy the use of the gnomon for latitude rendered this operation extremely difficult and uncertain, the calculations for longitude being based upon itineraries of travelers. The next forward step was taken by Hipparchus, a Greek of Rhodes, about 160 B. C., who showed how to determine longitude by eclipses of the sun and moon, and who also ancient MSS. represent the original series. Many maps published with later editions of this geography are certainly not by him, but constructed by his editors from the descriptive and mathematical text.

Geographical discovery in the fifteenth and sixteenth centuries gradually undermined Ptolemy's authority and proved the unsoundness of his fundamental assumptions both as to the length of the circumferential arc and the relative locations of initial positions. The geographers of the sixteenth century took up again the subject of spherical projection, modifying those of Hipparchus and Ptolemy and inventing new ones. John Ruysch, in 1508, substituted for Ptolemy's circumscribed cone an inscribed cone with its apex at the pole and its base at the equator. Apianus, in 1524, and Cabot, in 1544, used the method of equidistant parallel and circular meridians. In 1527 Henry Lentz made known the method of projection by which the zones for geographical globes could be prepared. In 1554 appeared the great Mercator (Gerhard Kramer) who modified Ptolemy's tangent cone into an intersecting one, and also devised the projection on a tangent cylinder with parallels at such distances apart that the ratio of the degree of latitude to the degree of longitude is preserved the same as at a corresponding point of the sphere. Portel in 1851 published a world map on the globular or equidistant projection. A form of Flamsteed's projection, having rectilinear and sinusoidal meridians, was first given by Nicolas Lanson in 1650. Flamsteed, the first Astronomer Royal both on the central meridian and equator, increase from the center in the proportion of the sine of half of the arc. In 1805 Molleweide first described the projection of equidistant elliptical meridians with rectilinear parallels, which Babinet elaborated later under the name of Homalographic, publishing a series of atlases in which it is used. Sir Henry James, in 1858, used a modification of Lahire's so-called globular projection by placing the eye at a distance from the surface of the sphere equal to one-half radius. By using a plane parallel to the ecliptic and touching a tropic, he succeeded in constructing a single chart showing the four principal continents and embracing seven-tenths of the area of the globe.

All of these various methods of spherical representation, briefly recapitulated above, are, of course, inexact, and represent compromises. The two general deviations resulting from plane projection are distortion of form and exaggeration or diminution of areas. In hemispherical world maps it is generally more important to preserve relations of form than those of areas; while in maps designed for measurement and correct relation—topographic maps—it is essential that the areas should preserve their correct projections. The nature of the solution, therefore, will depend upon the purpose of the map; and the different projections invented may, therefore, be divided into three groups:

I. Those that preserve form—Orthomorphic.

II. Those that preserve the equivalence of areas—Equivalent.

III. Those that compromise between the two—Compensative.

Topography is concerned with the last two of these classes.

Again, the different systems may be grouped according to the method of so-called projection into:

I. Perspective projections.

II. Developments.

III. Conventional methods, in which arbitrary conditions are imposed upon developments.

The first are true projections and, from their nature, least suited to the preservation of equivalence of areas. The second are equally, from their nature, better suited to this use; and the last best of all, since they afford opportunity to correct the defects of the direct developments.

The method by development employs either the cone or cylinder—tangent or secant to the sphere—the secant surfaces balancing certain areas between the interior and exterior zones. The conventional methods, by arbitrary assumptions, correct and compensate for the exaggerations involved in the projections upon the plane, or upon the auxiliary developable surfaces; and, by their means, have been evolved the two most generally employed methods for topographic maps, that is, that of Bonne, just described; and the Polyconic, first suggested by Henry Loritz in 1527, and later described by the United States Coast Survey, and used in this country as well as in Great Britain for government surveys. The latter being the projection employed by the great government surveys of the United States, and adopted for its military maps, is the only one that need occupy the attention of the military topographers of this country. A description of its methods is given with others in the chapter on projections.

It was not until about the beginning of the seventeenth century that the topographic map had come to take on a form distinctly characteristic, and to separate itself definitely from the geographic map. Early topography, dating from this period until the close of the eighteenth century, was characterized by a pictorial rather than a conventional quality. The chief deficiency in these maps lay in their entire lack of scientific delineation of the hypsometry portrayed, as well as in their dependence upon astronomical observation alone for location. The earlier attempts to represent orographic features, both in geographical and topographical maps, were crude and without any efforts to achieve exact or even approximate definition of true form. It was usual to express both mountain ranges on geographical, and hill forms on topographical maps by a sort of bird's eye perspective; and even in the conventions employed in the maps of the seventeenth and eighteenth centuries it was customary to use, to a large extent, pictorial rather than conventional symbols.

In some of the maps this has been carried to such an extent as to result in a compromise between a map and a bird's eye pictorial view of the country described. It was also customary in the publications of this period to accompany the maps with careful bird's eye drawings of special objects, such as cities, fortifications, and notable localities. These were very beautifully executed and constituted a very interesting addition, from a historic standpoint, to the maps of the period. They have even a more important function from the military standpoint, since these drawings of fortifications and walled towns and their approaches must have been of incalculable value to the commanders of besieging armies. The functions of these drawings correspond to those of the military field-sketch of to-day.

A great amount of time and labor was expended in the elaboration of the maps of this period, and many of them are beautiful examples of the engraver's art, having been executed on copper plate with the utmost refinement and with a profusion of ornamental detail which though interesting would be considered wholly out of place in the map work of the present day. The student will find in the work of William and John Blaeu, who published in 1647 a splendid atlas which they entitled "The Theatre of the World," a very beautiful and interesting example of the geographic and topographic art of that time; also in the maps accompanying the history of the campaigns of Eugene and Marlborough, an equally fine example of copper-plate work.

Even the maps of the period of Frederick the Great are very deficient in topographic accuracy; and it was not until the end of the eighteenth and beginning of the nineteenth century that Napoleon's engineers developed topography into a well-considered and scientific form. It was before this time that Philip Buache, a distinguished geographer of the eighteenth century, devised in 1738 the idea of determining the line of intersection of parallel planes with the surface of the earth, and of representing their projections upon a horizontal plane. His application of this method of surface delineation by contours was intended wholly for hydrographic charts, but its first application was by Ducarla, in 1768, in a topographical map of Switzerland. In the Military School of Engineering at Mezières the idea of uniting the contour system of Buache with the system of hill shading by hachure lines was adopted under the inspiration of Monge, the author of modern descriptive geometry.

The first application of the shading of orography by hachures—or short line strokes systematically applied in the direction of slopes horizontally projected—was in the map of France of Cassini, but the hachures were not drawn under the limitations of an exact scale of shades, as in later systems, but as means of expression according to the taste of the draftsman.

The combination, therefore, adopted at Mezières was the first attempt to give a scientifically exact expression on the map to topographical relief. There at once arose a struggle between the partisans of different systems of illumination—those favoring the vertical illumination, who adhered to exact geometrical expression, and those advocating oblique illumination, who preferred more vivid and artistic expression. The result was a divergence of practice; the School of Application of Artillery and Engineering adhering to the vertical system, while the Polytechnique adopted the oblique. This was the outcome of the action of an imperial commission appointed by Napoleon in 1802 to give uniformity to topographic conventions; and it was not until 1828 that the action of another commission definitely enforced the adoption of direct illumination. The simplification of all conventions and a more accurate expression of topographic relief characterized the French maps; and from this time on throughout the nineteenth century the persistent tendency in all cartography has been toward the attainment of the highest scientific accuracy in the expression of relief, and a careful systematizing and conventionalizing of all signs and symbols used for the expression of "culture."

Since the early part of the nineteenth century two general methods of expression for topographic relief have been employed, both depending upon the intersection of the surface of the earth by a system of equidistant parallel planes. The first of these methods relies for expression of form upon the varying degrees of shade values proportional to the inclination of the surface of the ground to the horizon, artificially rendered by hachures; the other upon the relative approximation of the curves of intersection of the equidistant planes projected upon the plane of the map. In the first method these curves, called *contours*, are also used, but only to guide the draftsman in the drawing of the shaded strokes, called *hachures*, by which the varying degrees of shade values are expressed. The contours in the first system disappear from the map, and the degree of declivity is estimated from the intensity of the shade values, or the thickness of the shading strokes employed, or the number used within a definite length of contour. In the latter method the contours remain on the map and are sufficiently multiplied to produce by their approximation or divergence a sense of shading which gives without hachures a sufficiently graphic idea of the hill form, at the same time enabling the user to determine with much greater accuracy the actual degree of declivity by a knowledge of the height of each contour above the datum plane.

The latter system is gradually displacing the former, which has the great disadvantage of an absence of any exact scale of heights, and which by the intrusion of a large number of shading lines greatly obscures the surface of the map, and tends to confuse the expression of *culture*. The contour system can equally well be made the basis of an artificial shading applied as a wash or by rubbing with some shading medium of sufficient delicacy not to obscure either the contours or culture; and this method of auxiliary shading has been adopted in the latest maps of the general staff of France. The maps of the United States Geological Survey are excellent examples of the simple contour system and of the very satisfactory expression of relief effected by it in most forms of orography.

The remarkable advance of the topographic art during the past century, and the establishment by civilized governments of great geographic and topographic bureaus, have tended to unify map work throughout the world; and undoubtedly, in the not distant future, the principal governments of the world will adopt standard conventions and methods for the production of all maps.

(To be concluded.)

WATER IN ANTHRACITE MINES.

The quantity of water delivered to the surface per minute is of interest as an evidence of the great expense entailed upon the anthracite companies in connection with the mining and preparation of anthracite for market. An average of the amount of water pumped per minute during the last six years is about 445,000 gallons which amounts to 233,892,000,000 gallons per year, or 870,000,000 tons. In addition to the pumps used for unwatering the mines there are many bailing plants used, and while the Department of Mines has not gathered the data for these bailing plants, such data as have been published show that probably 50,000,000 tons of water per year is bailed from the anthracite mines. During this period there has therefore been raised about 15 tons of water through the year for every ton of coal brought to the surface, the average production during the year in question having been 60,721,590 tons per year. In order to take care of the water during times of excessive rainfall it is necessary to have a pumping capacity of practically double the average amount pumped. As is well known, in certain regions at certain times of the year even this capacity is not sufficient to keep the mines unwatered, hence it is fair to assume that at certain times at least 30 to 50 tons of water are being brought to the surface for every ton of coal raised.—Mines and Minerals.

TITANIFEROUS ORE OF IRON MOUNTAIN, WYOMING.

Iron Mountain, in southeastern Wyoming, in the east-central part of Albany County, is a rugged ridge of granular igneous rocks, 300 to 600 feet wide and 1¼ miles long, whose ragged top presents a marked contrast to the regular hogbacks of the foothill sedimentary rocks. It lies 8 miles west of Iron Mountain station, on the Colorado and Southern Railroad, from which it may be reached by wagon road, and approximately 40 miles northwest of Cheyenne. Chugwater Creek passes in a gorge through the iron ore body of the mountain.

The iron was first noticed September 30, 1840, by Capt. Howard Stansbury, U. S. Army, when he camped on the banks of Chugwater Creek on his way to Great Salt Lake. He found along the banks of the streams and in the adjacent hills "immense numbers of rounded black nodules of magnetic iron ore, which seemed to be of unusual richness." The greater portion of the main deposit passed into the hands of the Union Pacific Railroad as a part of land granted to it in 1862. In 1872 a wagon road was built to the deposit, prospectors rushed in, and the whole country was staked. In the following year a post-office was established, only to be abandoned a year later. Eight or ten years ago the Colorado Fuel and Iron Company employed 15 teams for several months in hauling ore from the mountain to the railroad, whence it was shipped to their smelters at Pueblo. The work was then suddenly abandoned.

This, in brief, is the history of the development of this region, whose economic possibilities are again awakening wide interest. In the fall of 1906 Sidney H. Ball, of the United States Geological Survey, visited the mountain, and he has prepared for the Survey's annual volume on economic geology (Bulletin No. 315, an account of the deposits.

The mass of iron ore forming the main deposit is an igneous dike, 1¼ miles long and 40 to 300 feet wide, its greatest width being at the point where Chugwater Creek cuts through the mass. A second dike of the iron ore, 6 to 20 feet wide, is exposed about 300 feet down stream (farther east) on the south side of the creek; and about one-eighth of a mile southeast of the south end of the main mass is a third dike, 10 to 30 feet wide and 300 feet long, with a trend approximately parallel to that of the main mass. Several smaller dikes, 10 to 50 feet long and none of them over 3 feet wide, lie east of this mass in parallel alignment.

The ore is a black, granular, holocrystalline rock, with metallic or sub-metallic luster, and, as chemical analyses show, contains a high percentage of titanium. By present smelting methods iron ores that contain so much titanium are almost valueless, as they are practically unreducible at the temperatures of blast or open-hearth furnaces. As a constituent of iron and steel, however, titanium increases toughness and tensile strength, and the production of high-grade iron from titaniferous ores is under some conditions profitable. Progress is being made in the treatment of these ores, and at some future time the deposits at Iron Mountain will doubtless be of great commercial importance.

Natural gas is to be furnished by the Columbia Gas and Electric Company to the city of Hamilton, Ohio, for a term of twenty-five years under a recently granted franchise. The company agreed to lease the mains of the municipal plant, maintain them and make necessary repairs, paying an annual rental of $5,750. Natural gas is to be supplied not later than January 1, 1908, the price to be 30 cents per 1,000 feet; should the supply fail, manufactured gas may be substituted at 60 cents. On July 6 the plant of the Hamilton Gas and Electric Company suffered considerably from a tornado. An auxiliary water-gas plant was called into service to meet the emergency, and the gas supply was restored in a few hours. The condensing house at the coke oven works was demolished; but it is expected to be in full working order in ninety days.

HEAVY FREIGHT TRAINS.

THE GROWTH OF CAR CAPACITY.

In Mr. Priestley's report on American railroads to the Indian Government, he emphasizes and reiterates again and again the use and value of statistics as they are compiled in the United States. Their chief value is attributed to the fact that they enable a railroad manager to compare the performances of to-day with those of yesterday or last month or last year and thus put himself in a position to curb losses and estimate the value of improvements. To those who are not in immediate charge, the interest in comparative statistics lies in the fact that they make it possible to keep posted as to the progress of events and the changes that have taken place in the methods of obtaining the same results or in doing the same thing. Thus attention has been called in these columns, from time to time, to the growth and development of the modern car and locomotive from those in use 25 or 30 years ago, and the changes have been startling. Most of this present condition has, however, come upon us so gradually that it is difficult to realize what it means until we resort to our comparative statistics and note what has actually been accomplished.

For example the gulf between the freight train weights of 10 years ago and now is greater than appears to the casual observer. To the man on the street there is but little difference in the appearance of the freight train of 1896 and of 1906. If he had counted the cars on some of our principal lines then and now he would have found what to him would seem an insignificant increase. For instance, he would have found trains averaging 47 cars long on a number of roads in 1896, and that these had grown to about 52 in 1901, and 56 in 1906. To be sure, this represents a growth of something more than 19 per cent in train length in 10 years; but, at the same time, he would have found that on some roads there had been an actual falling off in the number of cars hauled per train. In the case of the Middle division of the Pennsylvania, for example, which probably stands for the heaviest traffic on the line, there has been a steady decrease in the number of cars hauled per train during these 10 years. In 1896, the average number of cars loaded and empty hauled per train over this division was 54.52. In 1901 it had fallen to 50.04, and in 1906 to 42.83. So that it is evidently necessary to go behind mere external appearances in order to obtain a correct idea of what is being done.

That the growth of the car capacity has been very great we all know. It has risen from an average maximum of about 60,000 pounds to 110,000 pounds, and if a comparison of engine sizes were to be made on the same basis as that of train lengths first outlined we would find that, taking cylinder capacity as the standard, the 19-inch by 24-inch cylinder of 1896 had grown to 22 inches by 26 inches in 1901 and to 22 inches by 28 inches in 1906. And when this increase is coupled to a rise in steam pressure from about 165 pounds to 200 pounds, the tractive power of the locomotive rises accordingly and we find that its increase has been about two-fold, or from 20,000 to 40,000 pounds. This, of course, means that the actual tonnage hauled has increased in some relative proportion, for these heavy locomotives are not built, except in rare instances, to do the work of the lighter power that preceded them.

Taking the Middle division of the Pennsylvania as a concrete example of this—we find that the average weight of the trains was 1,326.11 tons in 1896; 1,448.63 tons in 1901, and 1,540.95 tons in 1906. As for the tractive power of the typical consolidation locomotives in these three years, it was 23,040 pounds for the first year and 39,688 pounds for the last two; thus showing an increase of about 72.26 per cent in tractive power, and but 16.2 per cent in the average weight of the train hauled. This must not be taken to mean that the extra increase in engine power is wasted, because in the figures given it is the average train load that is considered, and this includes not only all loading up to the capacity rating of the engine but light and empty trains, by which the requirements of railroad service will invariably cut the average down to a point far below the maximum. Where the figures are available and it is possible to separate the train weights in the direction of traffic from the empty haulage, the relation between the tractive effort of the engine and train weights is naturally much closer. For example, on the Chicago & Alton, on the double-track line between Bloomington and Brighton Park, the engines used in 1896 had cylinders 18 inches by 24 inches, and a tractive power of 18,176 pounds; in 1901, the cylinders were 21 inches diameter by 32 inches stroke, and the tractive power was 42,090 pounds; in 1906 these figures were 22 inches by 30 inches and 43,305 pounds. Meanwhile the train tonnage northbound was 1,350, 2,700 and 3,206 tons for the three years, respectively. A comparison of the increases for the three years may be stated as follows:

	Tractive power.	Train weights.
1896	1.00	1.00
1901	2.32	2.00
1906	2.33	2.37

This illustration shows that, in this case, at least, the engine rating has increased in almost exactly the same ratio as the tractive power. The greater increase of the former is undoubtedly due to the lower resistance per ton of the heavy train as compared with the light one; though in this instance there was a marked increase in the number of cars. In 1896 the train referred to contained thirty 60,000-pound capacity cars, while in 1906 there were 56 cars of 100,000 pounds capacity.

In collecting data regarding heavy train loads a letter from the superintendent of motive power of the Pittsburg & Lake Erie states that the "heaviest freight engines have 21-inch by 30-inch cylinders, with 50-inch drivers, and carry 200 pounds of steam, with a tractive power of 44,100 pounds. The average revenue train load for 1906 was 1,188 tons. This is probably the heaviest hauled by any railroad in the country. Were the southbound tonnage equal to the northbound, this train load could easily be run up to 2,000 tons. The rating for the engines given above is 3,500 tons, but they have hauled 4,200 tons and have made very good time. The train load for the past few years has increased about 8 per cent yearly."

On the Mohawk division of the New York Central the drawbar pull of the standard freight locomotives was 20,600 pounds in 1896; 31,200 pounds in 1901, and 47,100 pounds in 1906, and the average number of eastbound cars hauled in the three years was 46, 56, and 67, carrying a tonnage of 1,301, 1,834, and 2,421 respectively.

The Philadelphia & Reading tells the same story of a marked increase. Here the southbound tonnage from Reading to Philadelphia was from 1,950 tons in 1896 to 2,910 tons in 1901 and 3,300 tons in 1906. With the increased length of train and the greater weight of cars and engines, there has also come a slower average speed over the division in some cases, though this is not always true. The Middle division of the Pennsylvania is a notable exception to what appears to be the ordinary rule. For example, the time of slow trains was 11 hrs. 13 min. in 1896; 14 hrs. 29 min. in 1901, and 11 hrs. 47 min. in 1906; while that of preferred trains dropped from 9 hrs. 32 min. in 1901 to 7 hrs. 46 min. in 1906, showing that the facilities for handling the traffic have more than kept pace with the increase of tractive power and engine rating, since the time of delays has dropped from three to two hours, thus somewhat lowering the running speed, which is probably due to the higher proportional rating of the locomotive. This is, however, an exceptional state of affairs; for, in most cases the time required to cover a division has increased—increased both in the actual running time and in the delays, showing that not only is the speed slower because of the probable higher engine rating but that the traffic facilities for handling trains have not always kept pace with the increase of train load as combined with the greater number of trains, although in some cases the latter is not a factor of appreciable importance. An instance of this is found in one road where the average delays increased from 2 minutes to 1 hour and 3 minutes between 1896 and 1906, while but one train a day was added. Yet the average length of train was increased more than 45 per cent. In this case the delays can undoubtedly be traced to inadequate terminal facilities, as the yard that has to handle this traffic has been built up by accretions and is not particularly well adapted for rapid work with long trains. Other roads that show the same running speed as formerly present the same record of increase of delay time; while others again show both the falling off in running speed and increase of delay time that has been referred to, in some cases the delays having risen from 25 to 50 per cent, on an already liberal margin.

Now by reverting to the conditions set forth in the early portion of this paper we find that on the Pennsylvania Middle division there has been an actual falling off in train lengths so that yard capacity has merely been obliged to keep pace with the increase in the number of trains, which is apparently a far easier proposition than that of providing for extra and often extraordinary train lengths. In this case the traffic rose from 30 trains per day in 1896, to 45 trains in 1901 and 50 in 1906; and, as already stated, the delays dropped from three to two hours. There may be other causes contributing to this excellent showing, but it certainly does appear to be a fine demonstration of the value of keeping train lengths down to such dimensions that they are readily handled in the yards, a condition that can only be economically attained where heavy motive power is worked, by the liberal and almost exclusive use of cars of very high capacity.

Of course it is quite impossible to make a comparison of train lengths between different roads that would be of the slightest value because of the natural differences in the character of the traffic, grades, power, cars and terminal facilities; but, by comparing the past and present performances of individual roads, a general average of the increase of work done per train can be obtained, and this will probably average an increase that can be estimated at not far from 60 per cent; though, in individual cases, it will rise much higher than this. This latter is especially true where superintendents have gone tonnage mad and put up engine ratings to a point where delays and slow time will cut out all profit; and, in this, experience seems to show that short trains are better than long ones.

The elements that make for this increase of train load and render it of the greatest value are, taking the track to be of a suitable character, first the heavy power, then high capacity cars, and then suitable yard facilities. In this the high capacity car plays an important rôle by facilitating yard movements, and it appears to be of prime importance that the train should be made of a length that can be readily handled instead of being increased to such dimensions as to add to the delays that must always be vexatious under the best of conditions. Superintendents and managers are coming to a better realization of this and see that long trains are not always the most profitable. While it would be hazardous to say what will be the ultimate weight and length of train on any road, it is at least interesting to note the great advance that has been made along these lines during the past ten years, the means by which it has been accomplished, and the results that have been attained.—The Railroad Gazette.

THE CONTROL OF MONITORS.

The power of the water issuing from a monitor is enormous, and many men have been killed by monitors getting away from them. Improvements, however, have been made in handling them so as to render them comparatively safe. The effect of a monitor running away can be appreciated from the experience of firemen, where, with comparatively small hose and under small head, considerable damage may be done. If a 2-inch nozzle does this damage, the effect of an 8-inch or 10-inch nozzle and with water under a much higher head, can readily be appreciated.

The method of control in turning the monitor easily in any desired direction, is said to have been discovered in a peculiar way. A man wanted to clean his shovel; so he placed it alongside the water column as it issued from the monitor, and was surprised to see the monitor suddenly move. The foreman who had been watching the operation then rigged up a contrivance which has been subsequently called a deflector, which is a ring around the nozzle and which can be readily moved to allow the current of water to be projected against it. The pressure of a finger on the deflector is sufficient to turn the monitor around as the latter works in a ball-and-socket joint. The introduction of the deflector has undoubtedly saved many lives and greatly facilitated operations.

What promises to be one of the greatest improvements which have been made in hydraulic mining in the past few years is a device for operating and turning the monitor from a distance. The nearer the monitor can be placed to the bank the more effective will be the impact of the stream. The great danger of operation has been that where the bank is high, there is apt to be a fall of rock and dirt upon the men handling the monitor. An attempt to solve this has been made by the manager of the LaGrange Mine, in California, by the use of magnets to move the deflector, controlled by means of electric wires leading to the magnets of the monitor, thus enabling the latter to be placed very close to the bank and operated from a distance. This has been tried only on a small scale as yet, but it is thought it can be made practical for large monitors.—Mines and Minerals.

Covering Mass for Steam Pipes, Cylinders, Boilers, etc.—0.5 part of starch and 0.5 part of common sifted rye meal are mixed in cold water and gradually brought to a boil, then up to 150 parts of boiling water are added, constantly stirring and adding 0.125 to 0.25 part of well-crimped cow hair and 0.5 part of ordinary syrup or beet-sugar molasses. The whole, with 40 parts of white infusorial earth, is stirred into a dough. The mass is to be applied gradually, in thin layers, to the warm (not hot) machinery part, the previous layer being always allowed to dry thoroughly. Finally, coat with linseed-oil varnish and then with varnish paint.

THE NEWMAN KINEMATIC APPARATUS.

A CONTRIVANCE WHICH SIMPLIFIES THE STUDY OF MECHANISM.

Every student of mechanism is fully cognizant of the difficulty often encountered in thoroughly grasping the meaning conveyed by a text-book description of the properties of a particular mechanism, and the effect of altering its proportions, or to understand what curve may be traced by a given point on a moving body. Such difficulties may be partially overcome by the use of models, but under ordinary conditions a separate model is required for each mechanism, and then unless the model is adjustable the effect of varying the proportions cannot be demonstrated. Naturally the properties of a given mechanism can be worked out very fully on the drawing board; but such methods are slow, and if one desires to test the effect of altering the proportions, the whole process has to be repeated, which is a tedious proceeding.

As a remedy for these conditions Mr. W. H. Newman, a well-known English engineer, has recently devised an apparatus wherewith skeleton models of widely different mechanisms can be built up from the same simple elementary parts, and tested within a very short time. In evolving this apparatus the inventor has devoted special attention to keeping the elementary parts as few in number, and as simple, as possible. For all links and sliding rods flat steel in varying lengths is used; and on this rod joints can be clamped or blocks can slide. For joint pins and other purposes a uniform size of round rod has been adopted, and provision is made for holding a pencil lead in the end of the pin, so that it may trace out its path. The apparatus can be most conveniently employed on a special table consisting of two boards divided by a narrow slot, in which blocks are able to slide as shown in the accompanying illustrations of the applications of the apparatus. This slot is useful for crank and connecting-rod motions and so forth. Bridge tubes may be fixed across the boards in any position, and blocks holding pins can be clamped on these, so that a fixed pin can be located at any point over the board.

In one of our illustrations the various component parts of the apparatus are separately shown.

Some typical examples of the uses to which this kinematic apparatus may be applied are shown in Figs. 2 to 5. In Fig. 2 a Watt's and a Roberts's "parallel motion" are shown arranged on the same board and the curves traced by the "straight line" points. In the Watt's motion the use of the weights adopted for fixing the stationary points is shown; in the Roberts's motion, on the other hand, the two stationary points are fixed to one of the bridge tubes. The different curves are drawn by altering the position of the tracing point.

The ordinary single eccentric valve gear of a steam engine is shown in Fig. 3 automatically drawing the elliptical valve diagram. The two ellipses show the alteration caused in the valve motion by altering the angle of advance of the eccentric. The crank is double, the upper arm driving a short pin working in a block clamped to a bridge tube. The "eccentric" is a small crank working above the block. The valve rod is a piece of rod sliding in two blocks clamped to pins, which in turn are clamped in blocks on the same bridge tubes. A block with a pin in it is clamped to the left-hand end of the valve rod. From this pin a cord passes round pulleys to the end of another rod working in blocks parallel to the left-hand bridge tube. Another cord which passes over a guide pulley is attached to the other end of this second rod and has a weight at the end of it. This second rod will follow the motions of the valve rod but at right angles to it, being pulled in one direction by the valve rod and returned by the weight. The pencil is attached to the second rod, and so moves at right angles to the paper on the sliding board, which in turn is moved by the connecting rod.

Joy's valve gear is shown in Fig. 4. In this instance the paths of some points of the mechanism are drawn by a pencil put through the joint pins. The pencil drawing the valve diagram is in this instance moved by a cord and weight in a similar manner to that in Fig. 3.

The apparatus can also be utilized to great advantage for the investigations of cams and their proper-

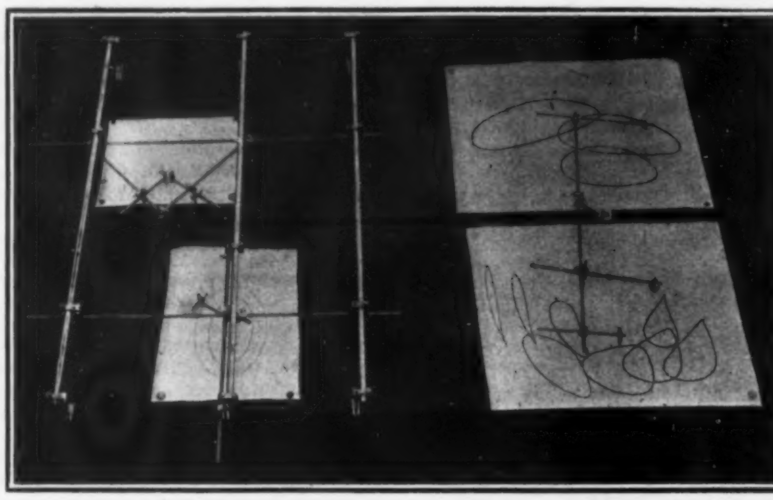


FIG. 5.—TWO MECHANISMS FOR DIFFERENT FORMS OF ELLIPSOGRAPHS, AND A MECHANISM CONSISTING OF A CRANK AND A LINK SWINGING ON A FIXED CENTER.

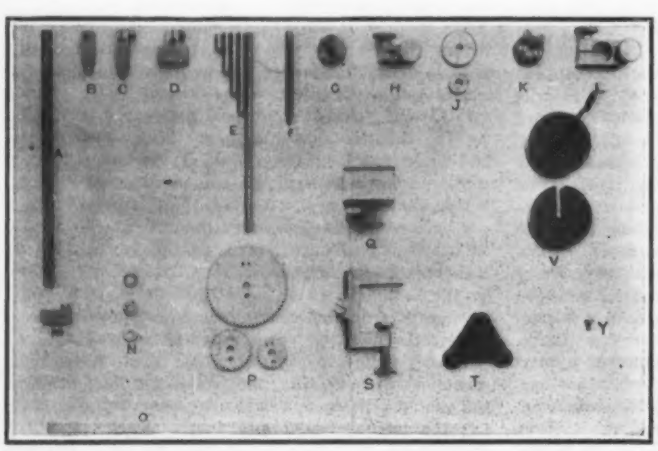


FIG. 1.—THE VARIOUS COMPONENT PARTS OF THE NEWMAN KINEMATIC APPARATUS FOR THE STUDY OF MECHANISM.

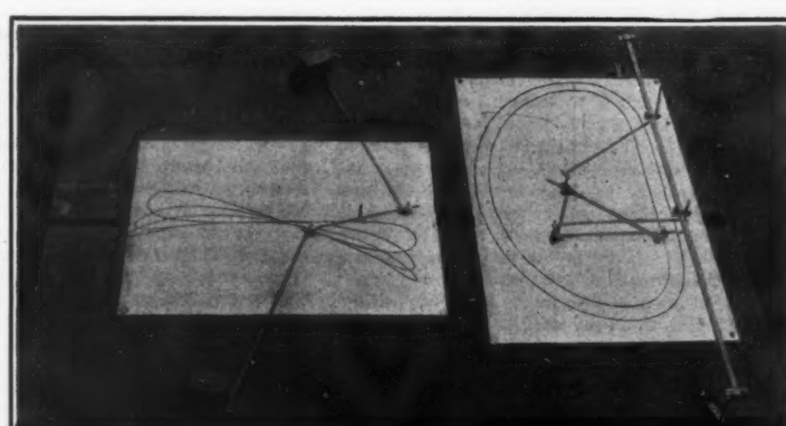


FIG. 2.—WATT'S AND ROBERTS'S "PARALLEL MOTIONS" ARRANGED ON THE SAME BOARD; THE CURVES ARE TRACED BY THE "STRAIGHT LINE" POINTS.

FIG. 3.—THE ORDINARY SINGLE ECCENTRIC GEAR OF A STEAM ENGINE AUTOMATICALLY DRAWING THE ELLIPTICAL VALVE DIAGRAM.

FIG. 4.—JOY'S VALVE GEAR, SHOWING THE DIAGRAMS DRAWN BY THE NEWMAN APPARATUS.

THE NEWMAN KINEMATIC APPARATUS FOR THE STUDY OF MECHANISM.

ties. A cam of the proposed form is cut out of millboard; working against it is a small roller carried on a sliding bar, which is connected by a cord passing round guide pulleys to another sliding bar carrying a pencil. The cam is clamped to a pin, which also has a crank clamped to it. The latter is coupled by the connecting rod to the sliding board on which the diagram is drawn showing the motion given by the cam.

In Fig. 5 the two mechanisms on the left are different forms of ellipsographs. On the right is a mechanism consisting of a crank and a link swinging on a fixed center. The end of this link and the crank pin are coupled by a connecting rod which is extended in both directions, and the curves are drawn by tracing points fixed at various positions on these extensions.

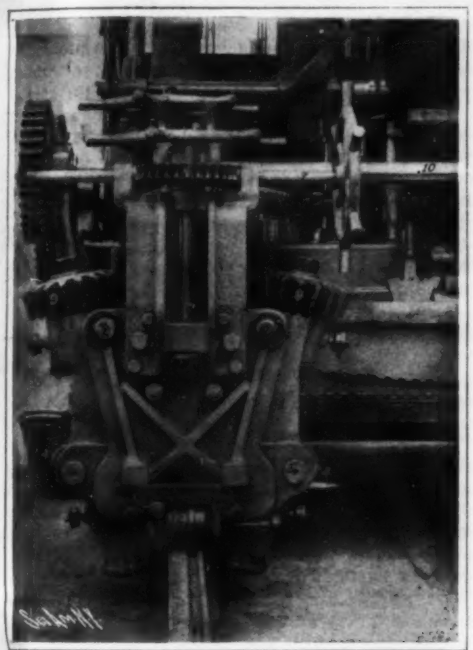
The value of the apparatus both to the student and to the practical designer may be comprehensively gathered. To the former it will often greatly assist in the better solution of an abstruse textbook problem, and to the practical man it offers an easy and rapid means for the investigation of some mechanical property, or the determination of the best proportions in the design of some new machinery.

A MACHINE FOR LAYING RAILS IN STREETS.

HOW TRACKS CAN BE LAID WITHOUT IMPEDING TRAFFIC

BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

EVERY engineer concerned in the construction and maintenance of street surface railroads is fully cognizant of the excessive wear and tear to which such



THE ROLLING APPARATUS FOR CLOSING THE FLANGES OF THE TOP RAIL ONTO THE HEAD OF THE PERMANENT BOTTOM GIRDER.

To cut the rail before stripping the upper section from the lower the outside roller is removed and a smooth disk cutter inserted.

tracks are subjected, and the expense and time, together with inconvenience to the vehicular and pedestrian traffic of the thoroughfare, that are necessarily involved when repairs and renewals to the rails become requisite.

In order to eliminate these drawbacks as far as possible, an ingenious system for constructing and laying the rails of the track, known as the "Romapac," has been introduced by a company of this name in Leeds (England), and by its utilization the renewal and repair of the rails is not only expedited and facilitated, but the cost of such operations is very appreciably reduced, while the disorganization of the other traffic in the thoroughfare in which such operations are in progress is reduced to a very appreciable degree.

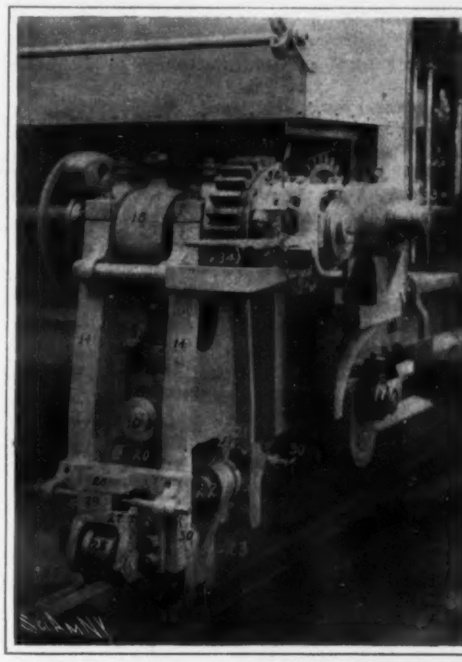
In the first place, with this system the present design of rail is entirely abandoned. As may be seen from the accompanying sectional diagram of a "Romapac" rail, it is constructed in two parts, one of which represents 59 per cent of the total weight of the rail, while the second part represents the remaining 41 per cent. The heavier section constitutes the permanent structure, and is an ordinary girder laid and tied in the usual way. The upper part of this girder is of flat-headed bulb tee section. Onto this is fitted the grooved rail in which the car wheels run, the under face being of channel section, and to secure the two sections rigidly together, the flanges of the channel section are closed so as to grip rigidly the head of the fixed girder, the process being carried out by cold welding. In this system only 41 per cent of the weight of the total rail is scrapped. The breaking of the conductor bonds joining each rail, the detachment of fish plates, ties, and the disturbance of the foundation are entirely obviated, as the permanent section is not touched at all. The disturbance of the road surface is reduced to the minimum, requiring the removal of only about 9 inches on either side of the rail; and as this material, be it either ballast or paving, can be removed and replaced in the minimum of time, this dislocation of the street traffic is very slight. Indeed, it is possible to carry out the whole operation of a long section of track during a single night, when vehicular traffic is at the minimum.

With this Romapac compound principle of construction the troubles at the rail joints are avoided by bridging the joints in the permanent girder, so that the joints of the renewable part of the rail are brought midway between the two ends of the lower section. This provides a stronger joint and one less liable to become low and "pound."

For the purposes of fixing together *in situ* the two sections of the compound rail the Romapac Company have designed an interesting plant, which is shown in the accompanying illustrations. With this appliance the various operations of stripping the detachable worn railhead and the rolling on of the new section are carried out, the mechanism for accomplishing these distinct operations being mounted on the portable trolley, rendering the machine self-contained.

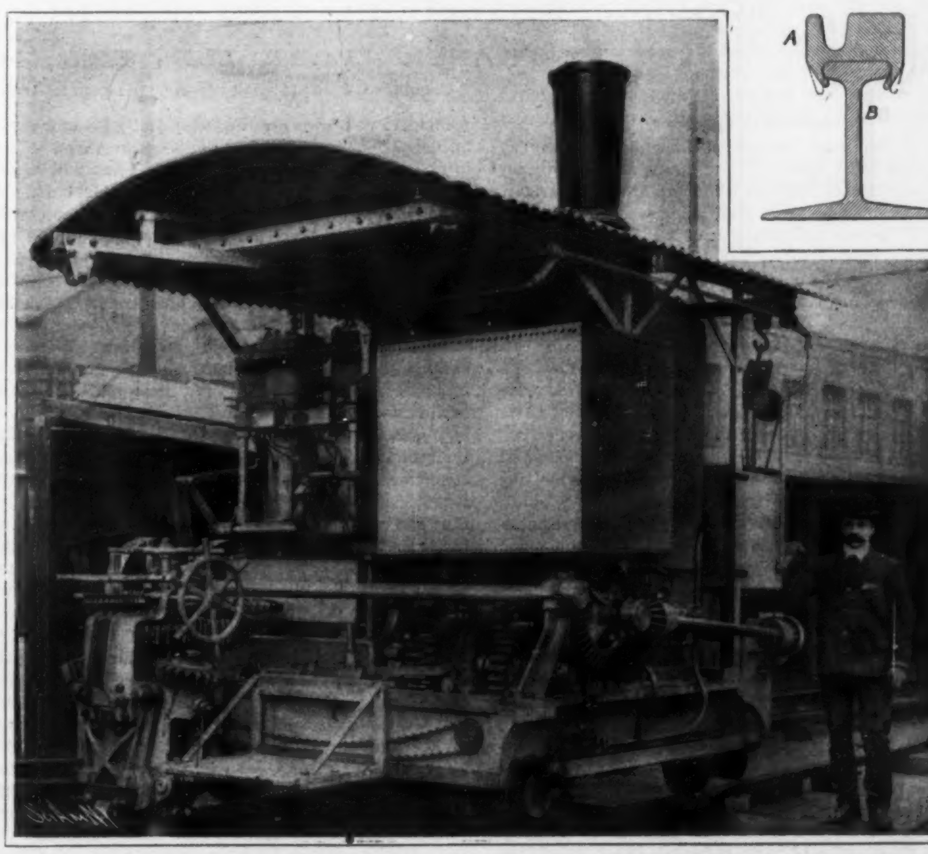
The machine consists of a locomotive with twin-cylinder inverted engine having a bore of 7¼ inches with a stroke of 10 inches, and a vertical multitubular boiler 3 feet 6 inches in diameter by 6 feet in height, with ninety tubes each 2 inches in diameter, mounted on a frame of planed cast iron, the ends being so made as to constitute cross slides, having a wheel base 5 feet 6 inches mounted on four coupled wheels 1 foot 3 inches in diameter and driven by two speed gears, the gearing being 2 to 1 and 20 to 1 respectively. The rolling and cutting machine is mounted on a saddle which fits on the front cross slide, while the breaking-off or stripping mechanism is mounted on the back cross slide. These latter two machines are driven by means of steel cross shafts having a keyway cut their full length upon which are sliding pinions with feathers, thus allowing the machine to follow curves. They are also equipped with lifting gear, so that they can be raised clear of the track when traveling to the required position, and also to enable them to be drawn across the cross slides and lowered on to the inner or outer rail for operation as required within the minimum of time.

The rolling-on machine consists of two iron side frames or cheeks between which fit the steel swing brackets 1, which are pivoted on the pins 2 at their upper ends, while their lower extremities are coupled



THE BREAKING OR STRIPPING APPARATUS OF THE MACHINE FOR REMOVING THE WORN TOP SECTION AFTER IT HAS BEEN CUT BY THE CUTTER.

by the pins 3 and toggle links 4 to the trunnions of a center nut, actuated by means of a buttress thread



Small diagram.—The Romapac combined rail, showing how the detachable tread section A is clinched to the bottom permanent girder B by the rolling machine. The dotted lines show the position of the flanges before closing.

THE ROMAPAC MACHINE FOR LAYING AND FIXING THE RAILS OF STREET RAILWAYS.

screw, which is geared by spur gearing and the worm wheel 6 to the hand wheel and shaft shown at 7. The swing brackets 1 are fitted with steel shafts having at their lower ends fluted and hardened steel rollers 8, and at their upper ends mangle tooth bevel-wheels 9, which are geared by means of bevel and spur reducing gear on the cross shaft 10. There are three steel flanged runners 12, which run on the rail fitted in a recess in the bottom of the cheeks or side frames in a steel carriage provided for the purpose. The fluted and hardened steel rollers can be raised or lowered to the requisite point for operation by means of packing strips 13.

In operation the rolling machine is lowered onto the top rail, which has been placed upon the permanent girder, until the three runners 12 are in contact with the tread of the rail, the rollers being on either side of the railhead. The coupled wheels of the machine are now thrown out of gear with the engines and geared with the rolling machine. The rollers are brought together so as to come into contact with and grip the depending flanges of the upper section of rail by means of the handwheel 7. The engines are then set in motion, the propulsive effort being supplied by the rollers and at the same time the handwheel is manipulated so as to bring the rollers to bear upon the flanges with the requisite pressure. The operation is confined to one length of rail at a time, and the ratio between the closing of the rollers and the traveling speed of the machine is in such proportion that from six to eight passes backward and forward over the rail is sufficient to close the flanges and give the required grip upon the permanent girder, the pressure of the rollers being increased with each repetition of the length of travel along the track.

For the cutting operations the rollers 8 are removed, and in their place is inserted a smooth disk cutter on the outside of the rail with a fluted steel roller on the inside to supply the necessary propelling power to the machine along the track. The operations are identical with those utilized in the rolling operations, the machine being traveled forward and backward over the rail until a groove has been cut on the outside flange to a depth of ¼ inch or half-way through the flange. The cutters and rollers are then removed, opened clear of the rail to permit the breaking of the rail to be carried out.

The breaking or stripping machine is mounted on a saddle fitted to the back cross slides and steel side frames, 14, fitted with bearings in which revolves a steel eccentric shaft 15. The eccentric strap 16 on the latter is connected by means of a right and left hand adjusting screw 17, rod-end 18, to a swing cross-head with trunnions 19, and by means of a connecting link 20, toggle links 21, and pins 22, to steel levers or jaws 23. These levers oscillate on pins fitted in a frame, which is free to slide vertically and transversely so as to allow these levers to adjust themselves to the rail. In the lower ends of these levers are dovetailed recesses, one side of which is formed by steel clips 24, which grip by means of the bolt 25 double-ended steel drag hooks. To the lower end of the cheeks 14 there are side plates 26, bolted in which are fitted steel carriages 27, fitted with steel runners 28, adjusting wedge blocks 29, and screws 30. Spur gearing 31 and friction clutch 32 gear the eccentric shaft 15 to the cross shafts 33, the spur gearing and clutch being actuated by the lever 34.

The operation of this breaking or stripping mechanism is as follows: When the outside flange of the upper section of the rail has been cut to the required depth by means of the cutter, the breaking machine is lowered until the runners 28 come into contact with the tread of the rail, the jaws 23 being one on each side. The steel drag hooks are inserted in the dovetail clips at the bottom end of the levers, with their inward ends engaging with the depending gripping flanges of the rail. The connecting-rod screw 17 is now adjusted so that the upward stroke of the eccentric first lifts the levers 23 and the floating frame until the tops of the pulling hooks are in contact with the under side of the bulb tee head, which prevents any further upward movement, the remainder of the stroke being then exerted in expanding the jaws sufficiently to open out and tear off the flange along the line of the cut made by the cutter. The machine is then put into the slow-traveling gear, which is in ratio with the speed of the breaking machine of 1 inch of travel to one pull of the breaking hook, the breaking machine making about 600 revolutions per minute and tearing the flange off.

The inventor of this labor-saving machine, Mr. E. Rhodes, an engineer of Leeds, has also devised special appliances to act in conjunction therewith, for use on curves, for the purposes of bending the rail to the required radius, and also a cutting machine for cutting the rail to the desired length.

Many severe tests have been carried out with the appliance before the leading engineers of the country, and the results have been remarkable, while the work has been closely inspected and tested to determine the degree of perfection that is possible. One of the most interesting of these tests was carried out by the well-known British engineer Mr. J. H. Wicksteed, formerly president of the Institute of Mechanical Engineers. In this case the top section was rolled into position in about eight passes of the machine accomplished in as many minutes, the flanges closing without betraying any signs of cracking, while the work of removing the top rail was effected as easily as the closing. He also tested a specimen of the rail both before and after closing. In the first instance the head rail was laid in position on the girder rail with the flanges unclosed, and their combined resistance to bending between 3-foot supports was found to be 43.75 tons, with a permanent set of 0.040 inch on the 3-foot span. When the upper rail was closed upon the lower girder, the resistance to bending was found to be 46.33 tons, with a permanent set of 0.040 inch on the 3-foot span. In this test the first sign of a perceptible creep of the top rail upon the girder rail in the action of bending took place with a load of 12 tons between supports.

It may be considered that by the constant passage of heavy trolley cars and the shocks that might be set up by the crossing of heavy vehicles over the track, the upper portion of the rail might become loosened. In order to ascertain the effects that might be produced from such causes, a section of a closed rail was submitted to continuous blows for a prolonged period from a steam hammer, the weight of which ranged from 336 to 784 pounds. The flanges of the upper rail, however, evinced no signs of coming apart, and were as securely joined together at the conclusion of, as prior to, the tests, showing that the possibility of the top rail becoming loosened by the wear and tear of the cars running constantly over them and other extraneous causes is successfully overcome.

The expense of constructing the renewing rails on this principle shows a decided economy as compared with the present system. The cost of the manufacture of the compound rail is stated to be no greater than that of the present type, while the saving on the cost of renewals is approximately 53.33 per cent, and the life of the rail is considerably prolonged by the method of staggering the joints in the top and bottom sections.

The advantages of this system will be apparent to any one concerned with street surface railroad engineering, where the cost of renewing the rails constitutes an appreciable item in the maintenance charges, both from the point of material and labor. The Romapac principle is being submitted to practical and comparative tests in Great Britain, a section of a track near Leeds being constructed on this principle for a distance of 495 feet. The track has been in operation for some six months, and it has proved to be eminently satisfactory.

UNSOLVED PROBLEMS IN THE DESIGN AND PROPULSION OF SHIPS.—II.*

LOADING, WATERTIGHT COMPARTMENTS, AND STABILITY.

BY FRANCIS ELGAR, LL.D., F.R.S., M.INST.C.E.

Concluded from Supplement No. 1650, page 103.

STRUCTURAL STRENGTH.

One of the most important elements of safety at sea is structural strength, and there is no more intricate, or difficult, problem which we have to consider. Mercantile steamers have been made what they are in respect of design and strength of structure chiefly by observation and experience of the effects of straining action at sea. The usual calculations of strength of structures do not carry us very far by themselves in shipbuilding; and although much attention has been given to these by ship designers, they cannot be greatly relied upon in practice. As a matter of fact, the arrangement of material shown upon the transverse section of a ship and the sizes of the various parts are practically what they have been made from time to time by Lloyd's Register Society. Classification at Lloyd's is so important in the mercantile marine, for purposes of insurance, that the design of a ship's structure is usually little, if any, more than compliance with Lloyd's rules and tables. I use the name Lloyd's in this connection as a generic term, which includes the other shipping registration and classification societies, as it is the one of outstanding and dominant influence. It is but seldom that structural design amounts to more than satisfying a registration society that its requirements for classification, as laid down in rules and tables, have been complied with. These rules have been modified as ships have increased in size and varied in type; and when exceptional ships not directly provided for by the rules have to be classed, the structural design is specially dealt with by Lloyd's. But the governing principle throughout is experience of the behavior of ships at sea. Lloyd's Society has representatives in all the principal ports of the world, who deal with and report all defects in the ships that come before them. There is no reason to fear that any weak point will escape the attention of Lloyd's surveyors. It is chiefly in this way that Lloyd's rules have been built up, from the earliest days of iron ships. The shipbuilding profession also owes very much to Lloyd's for what it has done and is still doing in scientific research. They have a highly trained technical staff which has conducted and published some of the most valuable investigations yet made of the structural strength of ships. But the general problem of how to obtain the requisite strength of structure in a ship with the minimum weight of material is extremely difficult of approach from the scientific side. The usual calculations of structural strength are based upon still-water conditions. The most useful are those which relate to longitudinal strength, because the greatest stresses that can come upon a ship are in the longitudinal direction. In these calculations the structure of a ship is regarded as a steel girder supported over the whole of its length by the upward pressure of the water. We can take a ship floating in equilibrium in still water, and calculate the distribution of the support from bow to stern that is given by the upward pressure of the water, which agrees with the curve of sectional areas of the under-water portion of the hull; and we can also calculate the weight of the ship and of her contents per unit of length, and represent that by a curve, or rather by an irregular line, which gives the longitudinal distribution of the weight of the girder and its load. With these two factors—the longitudinal distribution of load and the longitudinal distribution of support—the bending moments and maximum stresses upon the structure can be estimated according to the theory of the strength of girders.

In order to approximate more nearly to the worst conditions at sea, the maximum stresses upon the top and bottom of the structure are calculated for two hypothetical cases of support upon a wave surface. The surface usually taken is that of a trochoidal wave of the same length as the ship, whose height is one-twentieth of its length. The waterline is drawn to this wave form upon the side of the ship on the sheer drawing, so as to cut off the volume of her calculated displacement and place her in equilibrium (1) if supported amidships upon the wave-crest with her bow and stern in the hollows, and (2) if supported at the ends upon the wave-crests with her midship part in the hollow. The whole system of wave-water is supposed, for the purposes of the calculation, to be fixed for the moment, and the ship to be floating upon it in statical equilibrium.

It is not known how nearly the results obtained by calculation upon assumptions that differ so widely from the real circumstances correspond with the maximum stresses really brought to bear at sea, but it is certain that they are often in excess of the truth. In the new big Cunarders, "Lusitania" and "Mauretania," the limiting stress accepted by Lloyd's, as determined by calculation, was 10 tons per square inch, supposing the material to be mild steel whose ultimate tensile strength is 28 to 32 tons per square inch. This gives an apparent factor of safety of only 3.

Many vessels have been running for years in which the figures obtained by calculation for the maximum stresses would amount to 10 tons per square inch. This must be largely in excess of the truth, and it is impossible to say exactly by how much. One important cause of the excess, worked out in detail by Mr. W. E. Smith, of the Admiralty, many years ago, is, that the buoyancy of wave-water is not the same at all parts of the wave, being less at the crest and more at the hollow than that due to the weight of the volume

* The James Forrest lecture, delivered before the Institution of Civil Engineers, June 18, 1907.

of water displaced. This property of wave water can be allowed for approximately in the calculations, and the necessary corrections made. They effect a substantial reduction of the calculated stresses in both the extreme positions upon a wave surface; but they are not applied in practice, as the results are only used for purposes of comparison, and such a correction would not materially affect mere comparisons. The quantitative value of the calculated stresses is extremely doubtful in any case. Even in comparing them with figures obtained in a similar way for other ships it is necessary to be careful not to press the comparison too far. Attempts have been made to measure the actual stresses upon portions of the structure at sea by means of strain-indicators. Extensive experiments were carried out in H. M. S. "Wolf" a few years ago by an Admiralty committee with Stromeyer's indicators, which gave some interesting results; but very little real progress has yet been made in this direction toward a quantitative solution of the strength problem.

The strength of ships and the weight of the structural materials employed to obtain that strength, thus having become what they are by a long process of adding to, and building up the structure in detail, and reinforcing weak points wherever they have been found, and by checking the general results in the imperfect manner that is alone possible by calculations of the kind referred to, it becomes a question as to how far the results arrived at are satisfactory or final. All who have studied the great problems of ship design, and know how they were solved in the design of the "Great Eastern" by Mr. Brunel, must agree with the opinion expressed by Sir W. H. White, in his presidential address of nearly four years ago, that "in structure she was not merely a marvel considering the date of her construction, but is still a most fruitful and suggestive field of study." The "Great Eastern" proved herself, by her Atlantic voyages to New York and Quebec, and her subsequent experiences in the trying work of cable-laying in the Atlantic, to be amply strong enough for anything required of such a ship; and if we compare her structure with that of the standard ship of her dimensions and type to-day, which embodies the results of fifty years more experience than her designer had, it appears very remarkable. Sir. W. H. White came to the conclusion, which I believe is right, that after making full allowance for features of modern designs, that involve additional weight, which the "Great Eastern" did not possess, her structure was lighter than that of the corresponding ship of to-day, although the latter is built of steel 50 per cent stronger than the iron plates of the "Great Eastern," and the riveting of the edges and butts of plating is much more extensive and efficient, and is performed by hydraulic power where strength is most required.

The leading features of the "Great Eastern's" design included a very strong cellular double bottom, continued up the sides to the waterline, a double-plated upper deck of cellular construction, and two longitudinal bulkheads for about half the ship's length amidships, which connected the cellular upper deck with the double-bottom. There was no plating upon any deck except the upper deck. The structure of the corresponding steamer of to-day would consist of a very strong and deep double bottom of cellular construction, which is quite flat and stops at the turn of bilge, side plating above this, which is doubled at the upper part and is supported by very strong transverse frames about 30 inches apart, and four strongly-plated decks —the upper structural deck and three below it—of approximately equal strength, with a fifth plated deck above these, in many cases, for about half the ship's length amidships—at about 8 feet apart.

The difference in principle between the two designs is so great, and the comparison of the weights of material they require is so much in favor of the "Great Eastern," that there certainly seems to be a case for inquiry, and for considering the question of a radical change in the structural design of large ocean liners. Some such change is being introduced into the design of cargo steamers in order to obtain large open holds and facilitate stowage. These are now being built of large size and depth, with only a single-plated deck at the top, and there seems to be no reason why this principle should not be applied, to some extent at any rate, to large passenger vessels. Any saving of weight thus effected would not only be a saving of cost, but would better enable the difficulties of draft of water in harbor and docks for the largest ships to be overcome.

SPEED.

The problem of speed has always been a very vexed and difficult one, and there is none which has caused more trouble, or given rise to more fallacies in theory and errors in solution. I cannot even call attention now to the numerous theories and the various approximate formulæ that have been invented and employed from time to time for explaining and solving the speed problem. These formulæ are generally so restricted in their range of application, and require so much knowledge of their limitations, and the conditions under which they can be relied upon for results that will be approximately near to the truth, as to prove dangerous traps to the unwary and ill-informed. The man who can use these intelligently and safely, and with full knowledge of their limitations and tendencies to error, is able to deal with the speed problem much more completely and effectively; and I shall confine my remarks to the way of doing that.

The practical solution of the speed problem was effected by the late Mr. William Froude when he discovered the law of similitude or comparison which enables the resistance of a model, as ascertained by experiment, to be used for calculating the resistance of a model upon a different scale, or that of a full-sized ship of similar form. He found that, over and beyond surface friction and other minor causes of resistance that are about proportional to it in well-formed ships, and may for purposes of calculation be included in it, the only element of resistance is that due to the formation of waves which the passage of the ship through the water creates. When the forms of model and ship which originate the waves are similar, and travel at speeds proportional to the square roots of their respective dimensions, the wave configurations thus created will be similar in every respect, and be proportioned to each other upon the same relative scale as that of ship and model. Hence it may be deduced from theory that the resistance caused to these forms by the development of the waves would be proportional to the cubes of the dimensions of the forms.

The law of frictional resistance was investigated by experiment, and found to vary at a somewhat lower rate than the square of the speed, and to be affected by the absolute length of the surface immersed, and the figures for various natures and lengths of surface were determined experimentally by Mr. Froude. His analysis of the separate elements of resistance, showing that the two great ones—friction and wave-making —varied independently of each other, and the latter in a very irregular manner, explained why simple approximate formulæ are so untrustworthy.

What is wanted for the practical purposes of the designer is the means of ascertaining the resistance of a ship of given dimensions at any desired speed, and also of readily determining the precise form or degree of fineness of underwater body that will enable the maximum of carrying power to be obtained at a moderate rate of fuel consumption. It is one thing to know exactly what power is required to give a ship of given dimensions and form the speed asked for or promised, and another to determine what are the dimensions, form, and degree of fullness that will give the maximum passenger and freight-carrying capacity, with moderate engine power and expenditure of fuel. It is not uncommon to see ships built unnecessarily fine for the speeds at which they have to run, which might be made fuller and carry an increased weight of cargo without materially affecting speed and coal consumption. It is the determining of the precise limit of fullness of form that is advantageous in such cases, and upon which the success of a design often depends.

In order to exhaust the problem of the best form of ship to meet the requirements of any particular trade or service, considerable investigation is required. It can only be made satisfactory with models in an experimental tank upon the late Mr. Froude's system.

Dimensions and draft of water are usually fixed beforehand by commercial considerations, and by harbor and dock facilities, at any rate within somewhat narrow limits; and the designer requires to test models of varying degrees of fineness in order to determine the point at which the limit is reached beyond which the further increase of engine power and consumption necessitated by fuller lines would be unprofitable. This can be determined perfectly in an experimental tank. But that method is, unfortunately, impracticable for ship designers in general, because there is no tank in this country available for such purposes. The very few that exist belong either to the Admiralty or to private shipbuilders, and are confined exclusively to the work of their respective owners. I have had experiments made a few times for myself, but had to go abroad for the purpose. The tank experiments required by Mr. Yarrow for his valuable investigations into the effect of shallow water upon speed were made in the North German Lloyd tank at Bremerhaven, where other experiments have also been made for him. A British shipbuilder can only get such experiments made by setting up an experimental establishment for himself, or going abroad. Now an experimental tank, with its equipment and a competent staff for working it, is very costly to create and maintain; and over and above the mere cost of construction and of running it, there is the all-important question of the quality of the results it will produce. It is not enough to construct a tank and attach to it a staff of trained scientific men to run models and take records of their speed and resistance. The work is of so delicate and intricate a nature that the personal qualities of the experimenters count for very much in its value. The results obtained by the late Mr. W. Froude and the present Mr. R. E. Froude owe much of their value to the high qualifications of those gentlemen for such work and their great experience in it. It is the men, and not the tools, who constitute the most important factor in work such as this.

An attempt has recently been made to provide an experimental tank at the National Physical Laboratory, to be worked by members of the staff there, at which ship models might be tested for resistance; but up to now it has been without result. There is another way of dealing with the matter, however, and a better one for the ordinary purposes of the ship designer, which has been initiated by Mr. R. E. Froude, that promises to overcome the difficulty in a satisfactory manner. Mr. Froude read a paper at the Institution of Naval Architects, three years ago, upon "Some Results of Model Experiments," in which he gave results of a series of general experiments on systematic variations in form of hull, the variations consisting of six different sets of typical lines, varied in proportion by independent variations of length, beam, and draft. The resistance data given by these experiments are published in the paper in such a form that the resistance of a ship of any dimensions, whose lines are similar to the typical ones, which are also shown, can readily be taken out. The types dealt with have block coefficients, or ratios of displaced volume of water to product of length, breadth, and draft, varying from 0.4865 in the finest to 0.541 in the fullest. Now this series covers a very important class of mercantile steamers—that of fast Channel boats—and the designer of such a boat could have nothing better for his speed calculations than the data in this paper. He has only to refer to Mr. Froude's tables and curves in order to determine at once the proportions and form that will best suit the circumstances, and to construct the lines of his boat.

There could be no better solution of the speed problem for practical purposes than a continuation of the work that Mr. Froude has thus begun so well. This would be the greatest boon to ship designers. The method has been employed with most successful results in the practical design of ships of the class I have mentioned. I know of three vessels which have been made to approximate closely to Mr. Froude's forms, and whose estimates of speed have been based upon his data. The turbine steamer "Dieppe," which runs between Newhaven and Dieppe, is intermediate in form between Mr. Froude's No. 5 and No. 6 types. Her block coefficient of fineness is 0.538, with a waterline length of 280 feet and a speed of over 21 knots. She had to be increased in beam and made fuller in form than the previous vessels of the line, in order to carry additional weight, upon dimensions and draft of water that were strictly limited, without reduction of speed; and the best data available for determining the form that would fulfill these exacting conditions were Mr. Froude's. The result was a conspicuous success, as the "Dieppe" has proved to be the fastest boat of the line. The same procedure has been equally successful and satisfactory in the new turbine steamer "Viper," of the Burns line between Ardrossan and Belfast, another 21-knot boat whose lines are those of Mr. Froude's No. 4 type; and also in the twin-screw steamer "Hazel," fitted with ordinary reciprocating engines, just built for the Laird line between the Clyde and North of Ireland, whose length is 260 feet, and service speed 18 knots, and whose lines are based upon those of Mr. Froude's No. 4 type.

These results of the practical employment of Mr. Froude's methods and data are sufficient proof, if proof were needed, of their value; and one may say that for the ships represented by his types, the ship designer is thus practically independent of further tank experiments. The power and speed data necessary are all recorded in Mr. Froude's curves and tables, ready for immediate application. If similar data could be obtained for other forms of ships—say, for the fast-liner type—with block coefficients varying from about 0.6 to 0.7, the designer of that class of vessels would, indeed, have cause to be grateful. The best practical solution of this long-vexed problem of speed appears to be an extension of Mr. Froude's system to vessels of the fast-liner type, and others with which the ship-designer ordinarily has to deal, leaving those of abnormal proportions or form, and freaks, and also the work of general research, to a public experimental tank—if ever we find enterprise enough among those interested to get one set up in this country.

SCREW PROPELLERS.

The resistance of a ship may be estimated to a close degree of accuracy in the manner mentioned, but the determination of the engine power required to overcome that resistance involves the consideration of screw propeller efficiency. The problem of the most efficient design of propeller for a given size and form of ship and rate of turning of shaft is as yet far from practical solution.

Several attempts have been made to construct a theory for the action of the screw propeller. These involve, however, certain ideal assumptions for simplifying the problem, which would otherwise be too complex for theoretical treatment. It does not seem likely that any purely mathematical theory will be found suf-

ficiently reliable to enable the best screw dimensions to be determined for a given ship, and consequently we are bound to fall back upon the experimental method. It is this method which was developed by the late Mr. W. Froude, and has been continued by Mr. R. E. Froude in the Haslar tank. Model experiments have been carried out on a large number of propellers of varying pitch, diameter, and developed area, but these model screws have been very small, the size and speed at which they could be worked being limited by the stresses which the experimental mechanism is capable of bearing. This difficult has been greatest in the case of screws for turbine vessels, because the shafts necessarily run at much higher revolutions in them than with reciprocating engines, increased speed of turning being necessary to secure good turbine efficiency.

In applying the model screw results to full-sized ships, recourse must be had to a law of comparison similar to that obtaining between the model of the hull and the full-sized ship, and in this direction it is of great importance that further investigation should be made. Further advance might probably be effected by carrying out experiments in a tank on a larger scale than those already made, and with stronger appliances than those now used for the purpose in the Admiralty tank. A still more effective means, which I hear is under consideration by Mr. Froude, would be to build an experimental launch for the purpose, to be run in open water and propelled by machinery of considerable power. The propelling machinery could be so arranged that the thrust of the screws and the torque on the shaft could be automatically recorded, as in the case of tank experiments. With such an arrangement screws up to 3 feet in diameter could be experimented with—a great advance on anything that could be hoped for in the tank—and the important problem of propeller efficiency might thus be brought within reach of practical solution.

We now come to the greatest problem of all with regard to the propulsion of ships, and that is, the form which propelling machinery is likely to take in the immediate future. Already an important change is in progress from the ordinary reciprocating marine engine to the steam turbine; and the question is not only how far that change will extend, but also whether the whole of the cumbrous apparatus required for producing steam may not before very long be swept out of mercantile steamers, and the power be obtained from some form of internal-combustion engine. It would be rash to attempt to prophesy what will happen, but a short reference to what appears to be the present position with regard to these fundamental questions might be expected.

The progress of the steam turbine is remarkable. It has often been described by Mr. C. A. Parsons and others, and is pretty well known. The reason why its progress has not been greater, and why it is not already more generally employed in ships of all classes, are not so well known, and it might be useful to consider them. The Parsons steam turbine has practically superseded the reciprocating engine in the battleships, cruisers, and smaller very fast craft of our navy; and it has had equal success in the very important class of Channel steamers and other boats of similar type. Turbine steamers now employed on cross-channel services are running at speeds that could not be reached with the best reciprocating engines. They are strictly limited in many cases to a very shallow draft of water; they carry very little deadweight of coal and cargo; the weight of their machinery and boilers constitutes a large proportion of their gross weight, and the percentage of the latter that is saved by the use of fast-running turbines is sufficient to give a substantial advantage in speed.

IMPROVEMENTS IN EDISON'S SECONDARY BATTERY.

THE SIMPLIFIED DESIGN OF THE NEW CELLS.

To simplify the mechanical construction of storage batteries and at the same time improve their operation and increase the efficiency is the avowed object of two inventions by Thomas A. Edison, upon which patents have recently been granted by the United States Patent Office. Patent No. 852,424 relates to general

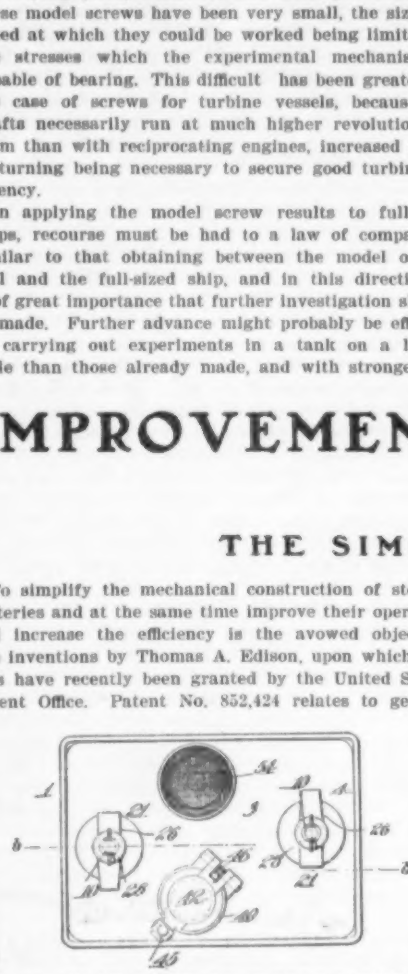


Fig. 1.—PLAN VIEW OF CELL OF EDISON STORAGE BATTERY.

improvements designed for use in storage batteries wherein insoluble active materials are employed in an alkaline electrolyte, especially batteries of the type invented by Mr. Edison. Patent No. 850,913 covers a division of the first application and relates to a relief valve and gas separator for the battery receptacle.

Fig. 1 is a plan view of the complete cell. Fig. 2 shows an improved separator for mechanically separating the plates; it is a horizontal section on line *a a* of Fig. 3, which itself is a vertical sectional view on line *b b* of Fig. 1. Fig. 4 shows a preferred form of insulating support for the plates, being a section on line *c c* of Fig. 3. Fig. 5 is side elevation, partly in section, showing the relief valve and gas separator applied to a storage battery.

The containing vessel or can is generally rectangular, as shown, being formed preferably of very thin sheet steel which has been carefully nickel-plated, so as to prevent oxidation, particularly in an alkaline solution. The bottom (2) is secured in place by an interlocking joint so as to make a water-tight joint even if solder is not used. The top (3), Fig. 3, is provided with an upturned flange (4) having a return flange (5) so as to receive the upper end of the can.

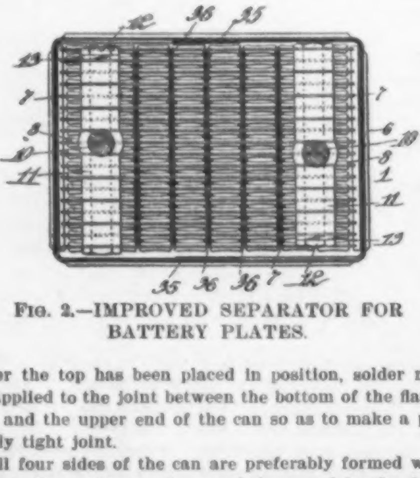


Fig. 2.—IMPROVED SEPARATOR FOR BATTERY PLATES.

After the top has been placed in position, solder may be applied to the joint between the bottom of the flange (5) and the upper end of the can so as to make a perfectly tight joint.

All four sides of the can are preferably formed with corrugations (6) struck out of the metal in the form of connected waves. The corrugations are interrupted at the corner of the can (see Figs. 2 and 3), whereby panels of corrugations entirely surrounded by plane metal are formed in the walls of the can. By corrugating the can in this way it is materially strengthened against compressing and bulging strains.

The grids (7), Fig. 3, are substantially like those described in prior Edison patents, and carry a plurality of pockets (8) containing the active material. The sides of the pockets are concaved as shown, so that when any swelling of the active material takes place the bulging of the pockets will not progress materially beyond a straight line. If the pockets are not concaved, excessive bulging tends to bring the pockets of adjacent plates into dangerous proximity with one another to increase the possibility of short-circuiting

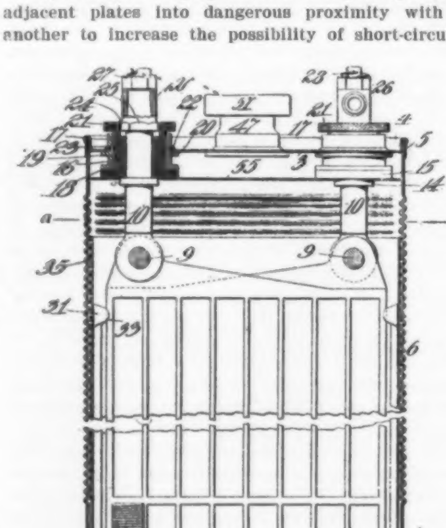


Fig. 3.—VERTICAL SECTION OF COMPLETE CELL OF EDISON STORAGE BATTERY.

when they are placed close together to save using an excess of electrolyte. This feature of concaving the pockets of a storage-battery plate is described in a patent granted to Mr. Edison on March 24, 1903. It is said that electrolytically active nickel swells or bulges to a much greater extent than the iron.

Corresponding plates of the battery are connected together and are mounted on bolts (9), which pass also through the eye of a proper conductor (10) for the external circuit. The plates of each set are separated by washers, and all the plates are held rigidly together, a hardened split spring washer of ordinary construction being employed on each bolt for locking the nut and preventing accidental loosening thereof.

The hard-rubber nut (21) is provided with a hexagonal recess (24) therein, with which engages the correspondingly shaped portion (25) of a terminal (26), the latter fitting over the tapered outer end of the conductor (10), and being held in place by a nut which is locked from rotation by a split washer. By means of this construction the conductor will not only be secured in position in such a way as to prevent

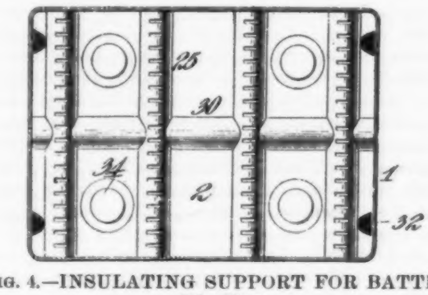


Fig. 4.—INSULATING SUPPORT FOR BATTERY PLATES.

creeping of the solution around the same, but will at the same time be effectively insulated from the corresponding conductor for the other plates.

At their bottom the plates are received on a suitable insulating support, the preferred construction of which is indicated in Figs. 3 and 4. This support comprises the parallel bars (29) having saw slots in their upper faces, as shown, and made essentially U-shaped in cross-section, with the shallower bars (30) connecting the same, the whole being made of one piece and preferably of hard rubber. The several plates are forced tightly downward to engage the slots in this insulating support by the adjusting effect of the nut (21), so that the plates are prevented from longitudinal movement.

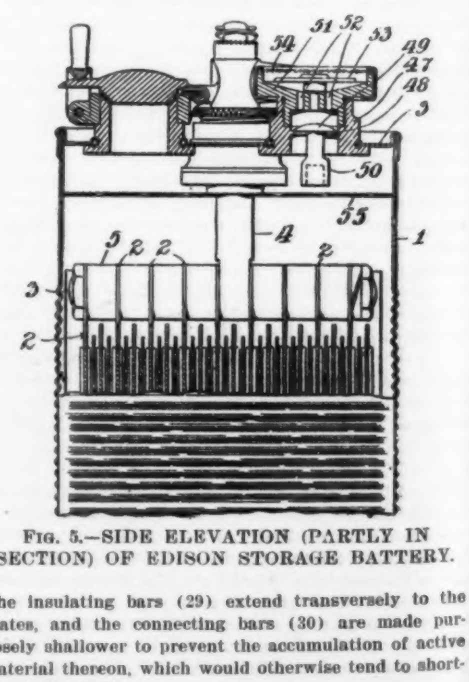


Fig. 5.—SIDE ELEVATION (PARTLY IN SECTION) OF EDISON STORAGE BATTERY.

The insulating bars (29) extend transversely to the plates, and the connecting bars (30) are made purposely shallower to prevent the accumulation of active material thereon, which would otherwise tend to short-circuit the plates.

In order properly to space the electrode plates at

the sides to prevent them from accidentally short-circuiting the cell, use is made of spacing bars (31) formed with slots therein, with which the electrode plates engage. These bars are connected together by vertical shallower bars (33), the whole being preferably cast of hard rubber in one piece. Preferably the bottom (2) of the can is provided with a number of struck-up bosses (34), forming sockets or recesses on the under side of the cell, in order that the latter may be properly supported in a suitable tray or crate.

In order to prevent the possibility of short-circuits between the plates by coming accidentally in contact with the side of the can, the interior of the can may be lined with a sheet (35) of hard rubber, and in order to prevent the plates from engaging one another, separating rods or bars (36), essentially star-shaped in cross-section, may be utilized, as shown in Fig. 2, the bars being mounted in the vertical channels formed between adjacent pockets, so that each bar engages the corners of four adjacent pockets, as shown.

In the operation of storage batteries employing either alkaline or acid electrolytes, gases are generated, due ordinarily to overcharging, which results in the decomposition of water, and these gases are highly explosive. The gases as they leave the solution carry with them mechanically entrained globules of the solution in the form of a very fine spray, which is objectionable, as it covers the battery and adjacent parts with a film of acid or alkaline solution, as the case may be. In the invention covered by the second patent provision is made for the escape of these gases, which may be generated in objectionable quantity, while at the same time effecting the complete separation of any globules which may be mechanically entrained therewith, so that the gases are no longer noxious. Provision is also made for preventing the ignition of any gases within the cell from outside influences, to thereby overcome the possibility of an explosion taking place. In the top plate or cover (3), Fig. 5, is secured a neck (47), carrying a valve seat (48), with which co-operates a small puppet or check valve (49), having a weighted stem (50), the valve being made preferably of hard rubber. Screw-threaded into the neck is a casing (51), having vent openings (52) therein, and above the vent openings is interposed a small dash-plate (53), which spreads and attenuates the escaping gases. The top of the casing is provided with a gauze (54), which operates like the gauze of a safety lamp to prevent the passage of the flame into the cell and the consequent ignition of any explosive gases therein. Such a contingency is further removed by the fact that the dash-plate causes any gases which may escape from the cell to be diffused and diluted, so as to therefore burn with difficulty.

Being projected from the cell with relative rapidity, the escaping gases, carrying with them the fine spray of solution, are projected against the deposited film of the solution on the inside of the bore of the cap (51) at the edges of the valve with sufficient force to overcome the surface tension of the film to thereby cause the mechanically entrained globules to coalesce with the film and be therefore effectively separated from the escaping gases. Consequently the escaping gases will be relieved of their objectionable character and will be no longer irritative. As soon as the rush of gas from the cell has taken place the weight of the puppet valve closes the latter and keeps the cell sealed until sufficient gas pressure has accumulated to cause these operations to be repeated.—Western Electrician.

A MAMMOTH CAVE CATHEDRAL.

SOME NEW DISCOVERIES OF INTEREST.

BY HORACE CARTER HOVEY.

Mammoth Cave abounds in surprises for those who forsake the beaten paths. In his revised map of this cave, part of which is used here, the writer shows a third more passageways than appear in any former chart. Some are mere tunnels, but others excel in grandeur all previously known subterranean halls. He has confirmed by personal observation reports concerning an extraordinary group of pits and domes, which it is the object of this article to describe.

An unexpected difficulty was encountered in the flooding of River Hall, due to the recent damming of Green River for steamboat navigation. This damming sets back the subterranean waters, so as to limit the period when it is safe to sail on them; besides seriously marring the matchless music by which myriads have been delighted on Echo River. The approaches were heavy with extremely sticky mud. We crossed Lake Lethe by boat, instead of skirting its margin; we paddled down the inundated "Great Walk," whose reaches of yellow sand used to be our admiration; and then by passing through "Purgatory" we reached the new landing Mr. Janin has had to make for Echo River under the new conditions.

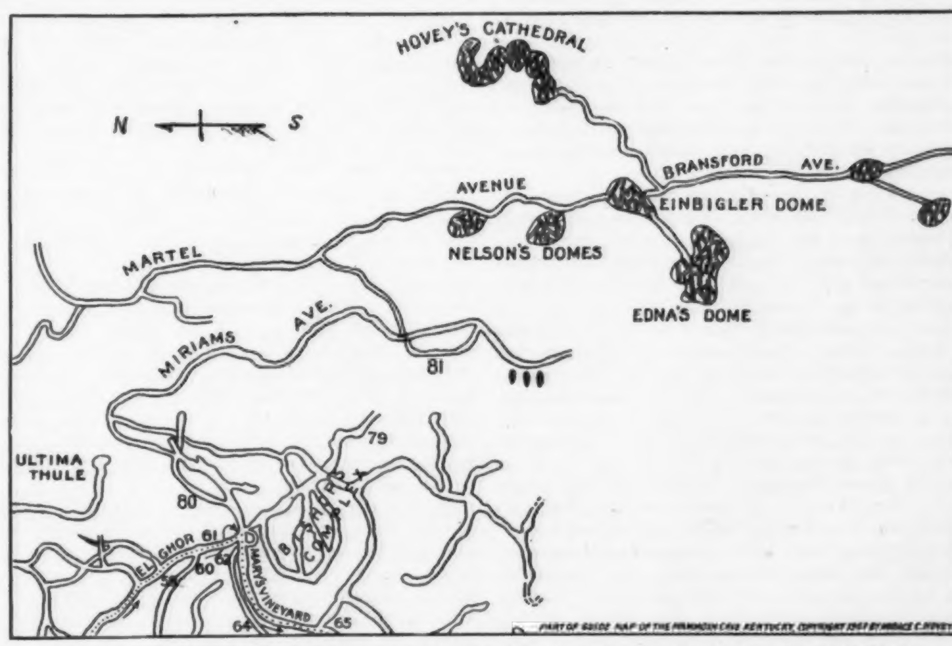
At Mary's Vineyard, 5,820 yards from the mouth of the cave, we diverged to the left into Boone Avenue (marked 80 on accompanying sketch), which has for many years been blocked by a stairway, recently removed. Proceeding by a well-worn path for some distance, we came to a chasm by whose opposite overhanging ledge we steadied ourselves while we picked our steps down to a lower level. This brought us into what is known on old maps as "Miriam Avenue." Presently we left this by a narrow and winding way which we named Pinson's Pass, through which we reached a long and noble passageway, not hitherto named, and to which we got permission to apply the name of the eminent French explorer and scientist, Edward A. Martel.

Martel Avenue opens right and left. The left-hand way is rough, leading to a few small pits. Taking the right-hand path, we soon come to what we surmised to be the bed of the Mystic River, mentioned by early visitors, but whose existence has been doubted. Ripple marks of sand alternate with broad, flat masses of jet-black flint highly polished by running water. The guide who first called my attention to this new region, Mr. John M. Nelson, says that he has here found decayed reeds, or corn stalks, and water worn knots and fragments of wood, indicating that they were swept down from the surface. Nelson's Domes are named for this skillful and intrepid guide. Beyond them we found an inscription on a rock, dated 1848, showing that some hardy pioneer had once reached this remote point. Mr. Norman A. Parrish came as far as this in 1904; but the distinction of availing himself of footholds over a risky limestone slip, and thus crossing beyond the deep abyss where others had turned back, belongs first of all to Mr. Benjamin F. Einbigler, of New York city, who did this May 15, 1905. In honor of him the great overhanging dome is named the Einbigler Dome. Only about a hundred yards beyond it he found a much larger cavity, which he named for his sister, who subsequently visited it, "Edna's Dome." Instead of narrowing to an apex, as other domes do, Edna's Dome grows broader at the top, seeming to open into some cross cavern. This is a mystery remaining for solution by future explorers. Nelson shot off fireworks without making the lofty roof visible.

A colored guide, Edward Hawkins, scaled the left wall of the pit previously mentioned, and found Hawkins's Way, May 15, 1907, being followed by Einbigler, Bransford, and later by Mr. H. M. Pinson, a local photographer, who took along for illumination the headlight of an automobile, and considerately left it there.

My own visit, next in order, came a month afterward, namely on the 18th of June, 1907, accompanied by two guides, William Bransford and Frank Barry, whom I found expert and willing men, without whom the trip could hardly have been made. More than once they served as stepping-stones over dangerous places, literally passing me from hand to hand where nature had failed to furnish footholds. Thus they helped me scale the wall and enter Hawkins's Way. At its termination our dim hand-lamps showed us to be in a large room, whose dimensions could not even be guessed until we lighted the auto headlight, for which I had brought along a fresh lot of carbide. Then its glare showed us to be on the level floor of a dome 60 feet in diameter, and from 150 to 200 feet in height. A tall arched gateway opened into a second dome of equal size; and then through other gateways we entered successively five domes arranged as a sigmoidal group. By climbing up between the fourth and fifth of the series, Nelson claims to have succeeded in reaching a large window that opens into an irregular room where a great downfall of rocks blocks further progress. Mr. Einbigler also is said to have reached this window by a ladder.

On careful inspection of this extraordinary place, we estimated the series to be four or five times the magnitude of Gorin's Dome, admired by thousands of visitors. The main floor is level and dry, but in the fifth dome is a waterfall that leaps from the apex to the floor and disappears in a chasm. The walls arise in horizontal tiers, eight or ten feet thick, each being fringed by stalactites, the mighty masonry rising, up, up, in ever-narrowing circles, till the brilliant acetylene headlight enables us barely to discern the irregular white oval tablet that forms the apex, and to catch a glimpse of its ornate border of onyx pendants. This imperfect description fits each of the series. Vertically the walls are richly corrugated from top to bottom, and are carved here and there with Nature's illegible hieroglyphics. The material is the same oolitic Saint Louis limestone from which the whole cave is carved. Age after age, in absolute darkness, and in silence broken only by the pattering waterfall or the heavier cataract, the slow process of erosion has gone on; till at last the task of chemical and mechanical aqueous action has resulted in this surprising and unequaled group of domes, from which we reluctantly turned away.



MAP SHOWING THE ROUTE TRAVERSED AND THE POSITION OF HOVEY'S CATHEDRAL.

Fidelity to the wishes of the management and guides requires the writer's grateful acknowledgment of their having given his name to this subterranean cathedral, in appreciation of his personal and enthusiastic half-century of cave exploration, here and elsewhere. At present the path to it is difficult and even dangerous in places; but it is the intention of the owners to make it at least safe, and in time as accessible as most other attractions in this majestic domain familiarly known as the Mammoth Cave of Kentucky.

Cement for Stereochromic Painting.—The mold is painted out with a mixture of 30 to 50 per cent of pure cement and a corresponding quantity, 70 to 50 per cent, of finely ground pumice-stone sand, and then, in the ordinary manner, a cement mixture, with one-third sand, filled in. Before the painting, the surface must be washed with dilute hydrochloric acid and saturated with water glass solution. Colors: Only mineral colors, fixed by water glass solution.

THE SCIENCE OF MEASUREMENT.*

ITS APPLICATION TO ASTRONOMICAL RESEARCH.

BY SIR DAVID GILL, K.C.B., F.R.S.

Lord Kelvin in 1871 made a statement as follows: "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than the looking for something new. But nearly all the grandest discoveries of science have been the reward of accurate measurement and patient, long-continued labor in the minute sifting of numerical results."

True as Lord Kelvin's words are in regard to most fields of science, they are specially applicable as a guide in astronomy.

One of Clerk Maxwell's lectures in the natural philosophy class at Marischall College, Aberdeen, in the year 1859, ran somewhat as follows: "A standard, as it is at present understood in England, is not a real standard at all; it is a rod of metal with lines ruled upon it to mark the yard, and it is kept somewhere in the House of Commons. If the House of Commons catches fire there may be an end to your standard. A copy of a standard can never be a real standard, because all the work of human hands is liable to error. It certainly will change by temperature, it probably will change by age (that is, by the rearrangement or settling down of its component molecules), and I am not sure if it does not change according to the azimuth in which it is used. If we used some natural invariable standard, such as the wave-length of the D-line of sodium vapor, we would be able to reproduce yard or inch, and our standard would be available anywhere in the universe where sodium is found."

That was the way in which Clerk Maxwell used to impress great principles upon his students. First they laughed; then some of them understood and remembered.

Now the scientific world has practically adopted Maxwell's form of natural standard. It is true that it names that standard the meter; but that standard is not one-millionth of the earth's quadrant in length, as it was intended to be; it is merely a certain piece of metal approximately of that length.

It is true that the length of that piece of metal has been reproduced with more precision, and is known with higher accuracy in terms of many secondary standards, than is the length of any other standard in the world; but it is, after all, liable to destruction and to possible secular change of length. For these reasons it cannot be scientifically described otherwise than as a piece of metal whose length at 0 deg. C. at the epoch A. D. 1906 is = 1,553,164 times the wave-length of the red line of the spectrum of cadmium when the latter is observed in dry air at the temperature of 15 deg. C. of the normal hydrogen-scale at a pressure of 760 mm. of mercury at 0 deg. C.

The length of the meter, in terms of the wave-length of the red line in the spectrum of cadmium, had been determined in 1892 by Michelson's method, with a mean result in almost exact accordance with that just quoted for the comparisons of 1906; but this agreement (within one part in ten millions) is due in some degree to chance, as the uncertainty of the earlier determination was probably ten times greater than the difference between the two independent results of 1892 and 1906.

We owe to M. Guillaume, of the International Bureau of Weights and Measures, the discovery of the remarkable properties of the alloys of nickel and steel, and from the point of view of exact measurement the specially valuable discovery of the properties of that alloy which we now call "invar." He has developed methods for treatment of wires made from this alloy which render more permanent the arrangement of their constituent molecules. Thus these wires, with their attached scales, may, for considerable periods of time and under circumstances of careful treatment, be regarded as nearly invariable standards. With proper precaution these wires can be used for the measurement of base lines of the highest geodetic precision with all the accuracy attainable by the older and most costly forms of apparatus; while with the new apparatus a base of 20 kilometers can be measured in less time and for less cost than one of a single kilometer with the older forms of measurement.

In connection with the progress of geodesy, time only permits a few words about the Great African arc on the 30th meridian.

The gap in the arc between the Limpopo and the previously executed triangulation in Rhodesia, has been filled up, and Col. (now Sir William) Morris has brought to a conclusion the reduction of the geodetic survey of the Transvaal and Orange River Colony.

Dr. Rubin, at the cost of the British South Africa Company, has carried the arc of meridian northward to S. latitude 9 deg. 42 min., so that we have now continuous triangulation from Cape L'Agulhas to within fifty miles of the southern end of Lake Tanganyika; that is to say, a continuous goedetic survey extending over twenty-five degrees of latitude.

It happens that, for the adjustment of the international boundary between the British Protectorate and the Congo Free State, a topographic survey is at the present moment being executed northward along the 30th meridian from the northern border of German East Africa.

This topographic survey will serve as the necessary reconnaissance. It will be completed by the end of January next, and the four following months offer the best season of the year for geodetic operations in these regions. It is hoped that use may be made of this survey to add to the arc. It is a matter of obtaining funds.

There is a staff of skilled officers on the spot sufficient to complete the work within the period mentioned, and the Intercolonial Council of the Transvaal and Orange River Colony most generously offers to lend the necessary geodetic instruments. The work will have to be done sooner or later, but if another expedition has to be organized for the purpose the work will then cost from twice to three times the present amount. One cannot therefore doubt that His Majesty's government will take advantage of the opportunity to vote the small sum required. This done, we cannot doubt that the German government will complete the chain along the eastern side of Lake Tanganyika, which lies entirely within their territory. Indeed, it is no secret that the Berlin Academy of Sciences has already prepared the necessary estimates with a view to recommending action on the part of its government.

Capt. Lyons, who is at the head of the survey of Egypt, has commenced preliminary operations toward carrying the arc southward from Alexandria, and we have perfect confidence that in his energetic hands the work will be prosecuted with vigor. In any case the completion of the African arc will rest largely in his hands. That arc, when completed, will extend from Cape L'Agulhas to Cairo, thence round the eastern shore of the Mediterranean and the islands of Greece, and there meet the triangulation of Greece itself, the latter being already connected with Struve's great arc, which terminates at the North Cape in lat. 70 deg. N. This will constitute an arc of 105 deg. in length—the longest arc of meridian that is measurable on the earth's surface.

Much progress has been made in the exact measurement of the great fundamental unit of astronomy—the solar parallax—as a result of the observations of the minor planets Iris, Victoria, and Sappho at their favorable oppositions in the years 1888 and 1889, which were made with the co-operation of the chief heliometer and meridian observatories. The sun's distance is now almost certainly known within one-thousandth part of its amount. The same series of observations also yielded a very reliable determination of the mass of the moon.

The more recently discovered planet Eros, which in 1900 approached the earth within one-third of the mean distance of the sun, afforded a most unexpected and welcome opportunity for redetermining the solar parallax—an opportunity which was largely taken advantage of by the principal observatories of the northern hemisphere. So far as the results have been reduced and published, they give an almost exact accordance with the value of the solar parallax derived from the heliometer observations of the minor planets Iris, Victoria, and Sappho in 1888 and 1889.

But in 1931 Eros will approach the earth within one-sixth part of the sun's mean distance, and the fault will rest with astronomers of that day if they do not succeed in determining the solar parallax within one ten-thousandth part of its amount.

And now to pass from consideration of the dimensions of our solar system to the study of the stars, or other suns, that surround us.

To the lay mind it is difficult to convey a due appreciation of the value and importance of star-catalogues of precision. As a rule such catalogues have nothing whatever to do with discovery in the ordinary sense of the word, for the existence of the stars which they contain is generally well known beforehand; and yet such catalogues are, in reality, by far the most valuable assets of astronomical research.

If it be desired to demarcate a boundary on the earth's surface by astronomical methods, or to fix the position of any object in the heavens, it is to the accurate star-catalogue that we must refer for the necessary data. In that case the stars may be said to resemble the trigonometrical points of a survey, and we are only concerned to know from accurate catalogues their position in the heavens at the epoch of observation. But in another and grander sense the stars are not mere landmarks, for each has its own apparent motion in the heavens which may be due in part to the absolute motion of the star itself in space, or in part to the motion of the solar system by which our point of view of surrounding stars is changed.

If we desire to determine these motions and to ascertain something of the general conditions which produce them, if we would learn something of the dynamical conditions of the universe and something of the velocity and direction of our own solar system through space, it is to the accurate star-catalogues of widely separated epochs that we must turn for a chief part of the requisite data.

The value of a star-catalogue of precision for present purpose of cosmic research varies as the square of its age and the square of its accuracy. We cannot alter the epoch of our observations, but we can increase their value fourfold by doubling their accuracy. Hence it is that many of our greater astronomers have devoted their lives chiefly to the accumulation of meridian observations of high precision, holding the view that to advance such precision is the most valuable service to science they could undertake, and comforted in their unselfish and laborious work only by the consciousness that they are preparing a solid foundation on which future astronomers may safely raise the superstructure of sound knowledge.

To extend exact measurement from our own solar system to that of other suns and other systems may be regarded as the supreme achievement of practical astronomy. So great are the difficulties of the problem, so minute the angles involved, that it is but in comparatively recent years that any approximate estimate could be formed of the true parallax of any fixed star. Bradley felt sure that if the star γ Draconis had a parallax of 1 sec. he would have detected it. Henderson by "the minute sifting of the numerical results" of his own meridian observations of α Centauri, made at the Cape of Good Hope in 1832-33, first obtained certain evidence of the measurable parallax of any fixed star. He was favored in this discovery by the fact that the object he selected happened to be so far as we yet know the nearest sun to our own. Shortly afterward Struve obtained evidence of a measurable parallax for α Lyræ and Bessel for 61 Cygni. Astronomers hailed with delight this bursting of the constraints which our imperfect means imposed on research. But for the great purposes of cosmical astronomy what we are chiefly concerned to know is not what is the parallax of this or that particular star, but rather what is the average parallax of a star having a particular magnitude and proper motion. The prospect of even an ultimate approximate attainment of this knowledge seemed remote. The star α Lyræ is one of the brightest in the heavens; the star 61 Cygni one that had the largest proper motion known at the time; while α_2 Centauri is not only a very bright star, but it has also a large proper motion. The parallax of these stars must therefore in all probability be large compared with the parallax of the average star; but yet to determine them with approximate accuracy long series of observations by the greatest astronomers and with the finest instruments of the day seemed necessary.

It was only in 1881, at the Cape of Good Hope, that general research on stellar parallax was instituted. Subsequently at Yale and at the Cape of Good Hope the work was continued on cosmical lines with larger and improved heliometers. By the introduction of the reversing prism and by other practical refinements the possibilities of systematic error were eliminated, and the accidental errors of observation reduced within very small limits.

These researches brought to light the immense diversity in the absolute luminosity and velocity of motion of different stars. Take the following by way of example:

Our nearest neighbor among the stars, α_2 Centauri, has a parallax of 0.76 sec. or distant about 4 1-3 light-years. Its mass is independently known to be almost exactly equal to that of our sun; and its spectrum being also identical with that of our sun, we may reasonably assume that it appears to us of the

* Abstract of presidential address delivered before the British Association for the Advancement of Science at Leicester, England, July 31, 1907.

same magnitude as would our sun if removed to the distance of α_2 Centauri.

But the average star of the same apparent magnitude as α_2 Centauri was found to have a parallax of only 0.10 sec.* so that either α_2 Centauri or our sun, if removed to a distance equal to that of the average fixed star of the first magnitude, would appear to us but little brighter than a star of the fifth magnitude.

Again, there is a star of only 8½ magnitude which has the remarkable annual proper motion of nearly 8¾ seconds of arc—one of those so-called runaway stars—which moves with a velocity of 80 miles per second at right angles to the line of sight (we do not know with what velocity in the line of sight). It is at about the same distance from us as Sirius, but it emits but one ten-thousandth part of the light energy of that brilliant star. Sirius itself emits about thirty times the light energy of our sun, but it in turn sinks into insignificance when compared with the giant Canopus, which emits at least 10,000 times the light-energy of our sun.

Truly "one star differs from another star in glory." Proper motion rather than apparent brightness is the truer indication of a star's probable proximity to the sun. Every star of considerable proper motion yet examined has proved to have a measurable parallax.

This fact at once suggests the idea, why should not the apparent parallactic motions of the stars, as produced by the sun's motion in space, be utilized as a means of determining stellar parallax?

The strength of such determinations, unlike those made by the method of annual parallax, would grow with time. It is true that the process cannot be applied to the determination of the parallax of individual stars, because the peculiar motion of a particular star cannot be separated from that part of its apparent motion which is due to parallactic displacement. But what we specially want is not to ascertain the parallax of the individual star, but the mean parallax of a particular group or class of stars, and for this research the method is specially applicable, provided we may assume that the peculiar motions are distributed at random, so that they have no systematic tendency in any direction; in other words, that the center of gravity of any extensive group of stars will remain fixed in space.

This assumption is, of course, but a working hypothesis, and one which from the researches of Prof. Kapteyn we already know to be inexact. But recent researches have shown that, at least for extensive parts of space, there are a nearly equal number of stars moving in exactly opposite directions. The assumption, then, that the mean of the peculiar motions is zero may, at least for these parts of space, be still regarded as a good working hypothesis.

Adopting an approximate position of the apex of the solar motion, Kapteyn resolved the observed proper motions of the Bradley stars into two components, viz., one in the plane of the great circle passing through the star and the apex, the other at right angles to that plane. The former component obviously includes the whole of the parallactic motion; the latter is independent of it, and is due entirely to the real motions of the stars themselves. From the former the mean parallactic motion of the group is derived, and from the combination of the two components, the relation of velocity of the sun's motion to that of the mean velocity of the stars of the group.

As the distance of any group of stars found by the parallactic motion is expressed as a unit in terms of the sun's yearly motion through space, the velocity of this motion is one of the fundamental quantities to be determined. If the mean parallax of any sufficiently extensive group or class of stars was known we should have at once means for a direct determination of the velocity of the sun's motion in space; or if, on the other hand, we can by independent methods determine the sun's velocity, then the mean parallax of any group of stars can be determined.

If by the application of Doppler's principle the velocities in the line of sight of a sufficient number of stars situated near the apex and antapex of the solar motion could be determined, so that in the mean it could be assumed that their peculiar motions would disappear, we have at once a direct determination of the required velocity of the sun's motion.

The material for this determination is gradually accumulating, and indeed much of it, already accumulated, is not yet published. But even with the comparatively scant material available, it now seems almost certain that the true value of the sun's velocity lies between 18 and 20 kilometers per second; or, if we adopt the mean value, 19 kilometers per second, this would correspond almost exactly with a yearly motion of the sun through space equal to four times the distance of the sun from the earth.

Thus the sun's yearly motion being four times the sun's distance, the parallactic motion of stars in which this motion is unforeshortened must be four times their parallax. How this number varies with the amount of foreshortening is of course readily calculated. The point is that from the mean parallactic motion of a group of stars we are now enabled to derive at once its mean parallax.

This research has been carried out by Kapteyn for stars of different magnitudes. It leads to the result that the parallax of stars differing *five* magnitudes does *not* differ in the proportion of one to ten, as would follow from the supposition of equal luminosity of stars throughout the universe, but only in the proportion of about one to five.

The same method cannot be applied to groups of stars of different proper motions, and it is only by a somewhat indirect proof, and by calling in the aid of such reliable results of direct parallax determination as we possess, that the variation of parallax with proper motion could be satisfactorily dealt with.

Consider, lastly, the distribution of stellar density, that is, the number of stars contained in the unit of volume.

We cannot determine absolute star-density, because, for example, some of the stars which we know from their measured parallaxes to be comparatively near to us are in themselves so little luminous that if removed to even a few light-years greater distance they would appear fainter than the ninth magnitude, and so fall below the magnitude at which our data at present stop.

But if we assume that intrinsically faint and bright stars are distributed in the same proportion in space, it will be evident that the comparative richness of stars in any part of the system will be the same as the comparative richness of the same part of the system in stars of a particular luminosity. Therefore, as we have already found the arrangement in space of the stars of different degrees of luminosity, and consequently their number at different distances from the sun, we must also be able to determine their relative density for these different distances.

Kapteyn finds in this way that, starting from the sun, the star-density is pretty constant till we reach a distance of some 200 light-years. Thence the density gradually diminishes till, at about 2,500 light-years, it is only about *one-fifth* of the density in the neighborhood of the sun. This conclusion must, however, be regarded as uncertain until we have by independent means been enabled to estimate the absorption of light in its course through interstellar space, and obtained proof that the ratio of intrinsically faint to bright stars is constant throughout the universe.

Thus far Kapteyn's researches deal with the stellar universe as a whole; the results, therefore, represent only the *mean* conditions of the system. The further development of our knowledge demands a like study applied to the several portions of the universe separately. This will require much more extensive material than we at present possess.

As a first further approximation the investigation will have to be applied separately to the Milky Way and the parts of the sky of higher galactic latitude. The velocity and direction of the sun's motion in space may certainly be treated as constants for many centuries to come, and these constants may be separately determined from groups of stars of various regions, various magnitudes, various proper motions, and various spectral types. If these constants as thus separately determined are different, the differences which are not attributable to errors of observation must be due to a common velocity or direction of motion of the group or class of star to which the sun's velocity or direction is referred.

Thus, for example, the sun's velocity is determined by spectroscopic observations of motion in the line of sight, appears to be sensibly smaller than that derived from fainter stars. The explanation appears to be that certain of the brighter stars form part of a cluster or group of which the sun is a member, and these stars tend to some extent to travel together. For these researches the existing material, especially that of the determination of velocities in the line of sight, is far too scanty.

Kapteyn has found that stars whose proper motions exceed 0.05 sec. are not more numerous in the Milky Way than in other parts of the sky; in other words, if only the stars having proper motions of 0.05 sec. or upward were mapped there would be no aggregation of stars showing the existence of a Milky Way.

The proper motions of stars of the second spectral type are, as a rule, considerably larger than those of the first type; but Kapteyn comes to the conclusion that this difference does not mean a real difference of velocity, but only that the second-type stars have a smaller luminosity, the mean difference between the two types amounting to 2½ magnitudes.

There is much work still to be done by astronomers. As the result of the Congress of Astronomers held at Paris in 1887 some sixteen of the principal observatories in the world are engaged in the laborious task, not only of photographing the heavens, but of measuring these photographs and publishing the *relative* positions of the stars on the plates down to the eleventh magnitude. A century hence this great work will have to be repeated, and then, if we of the present day have done our duty thoroughly, our successors will have the data for an infinitely more complete and thorough discussion of the motions of the sidereal system than any that can be attempted to-day. But there is still needed the accurate meridian observation of some eight or ten stars on each photographic plate, so as to permit the conversion of the *relative* star-places on the plate into *absolute* star-places in the heavens. It is true that some of the astronomers have already made these observations for the reference stars of the zones which they have undertaken. But this seems to be hardly enough. In order to coordinate these zones, as well as to give an accuracy to the *absolute* positions of the reference stars corresponding with that of the *relative* positions, it is desirable that this should be done for *all* the reference stars in the sky by several observatories. The observations of well-distributed stars by Kustner at Bonn present an admirable instance of the manner in which the work should be done. Several observatories in each hemisphere should devote themselves to this work, employing the same or other equally efficient means for the elimination of sources of systematic error depending on magnitude, etc., and it is of far more importance that we should have, say, two or three observations of each star at three different observatories than two or three times as many observations of each star made at a single observatory.

The southern cannot boast of a richness of instrumental and personal equipment comparable with that of the northern hemisphere, and consequently one welcomes with enthusiasm the proposal on the part of the Carnegie Institute to establish a meridian observatory in a suitable situation in the southern hemisphere. Such an observatory, energetically worked, with due attention to all necessary precautions for the exclusion of systematic errors, would conduce more than anything else to remedy in some degree that want of balance of astronomical effort in the two hemispheres to which allusion has already been made. But in designing the programme of the work it should be borne in mind that the proper duty of the meridian instrument in the present day is no longer to determine the positions of all stars down to a given order of magnitude, but to determine the positions of stars which are geometrically best situated and of the most suitable magnitude for measurement on photographic plates, and to connect these with the fundamental stars. For this purpose the working list of such an observatory should include only the fundamental stars and the stars which have been used as reference stars for the photographic plates.

Such a task undertaken by the Carnegie Observatory, by the Cape, and if possible by another observatory in the southern hemisphere, and by three observatories in the northern, would be regarded by astronomers of the future as the most valuable contribution that could be made to astronomy of the present day. Taken in conjunction with the astrographic survey of the heavens now so far advanced, it is an opportunity that if lost can never be made good; a work that would grow in value year by year as time rolls on, and one that would ever be remembered with gratitude by the astronomers of the future.

But for the solution of the riddle of the universe much more is required. Besides the proper motions, which would be derived from the data just described, we need for an ideal solution to know the velocity in the line of sight, the parallax, the magnitude, and the spectrum-type of every star.

The broad distinction between these latter data and the determination of proper motion is this, that whereas the observations for proper motion increase in value as the square of their age, those for velocity in the line of sight, parallax, magnitude, and type of spectrum may, for the broader purposes of cosmical research, be made at any time without loss of value. We should therefore be most careful not to sacrifice the interests of the future by immediate neglect of the former for the latter lines of research. The point is that those observatories which undertake this meridian work should set about it with the least possible delay, and prosecute the programme to the end with all possible zeal. Three observatories in each hemisphere should be sufficient; the quality of the work should be of the best, and quality should not be sacrificed for speed of work.

But the sole prosecution of routine labor, however high the ultimate object, would hardly be a healthy condition for the astronomy of the immediate future. The sense of progress is essential to healthy growth, the desire to know must in some measure be gratified. We have to test the work that we have done in order to be sure that we are working on the right lines, and new facts, new discoveries, are the best incentives to work.

For these reasons Kapteyn, in consultation with his colleagues in different parts of the world, has proposed a scheme of research which is designed to afford within a comparatively limited time a great augmentation of our knowledge. The principle on

which his programme is based is that adequate data as to the proper motions, parallaxes, magnitudes, and the type of spectrum of stars situated in limited but symmetrically distributed areas of the sky, will suffice to determine many of the broader facts of the constitution of the universe. His proposals and methods are known to astronomers and need not therefore be here repeated. In all respects save one these proposals are practical and adequate, and the required co-operation may be said to be already secured—the exception is that of the determination of motion in the line of sight.

All present experience goes to show that there is no known satisfactory method of determining radial velocity of stars by wholesale methods, but that such velocities must be determined star by star. For the fainter stars huge telescopes and spectroscopes of comparatively low dispersion must be employed. On this account there is great need in both hemispheres of a huge reflecting telescope—six to eight feet in aperture—devoted almost exclusively to this research. Such a telescope is already in preparation at Mount Wilson, in America, for use in the northern hemisphere. Let us hope that Prof. Pickering's appeal for a large reflector to be mounted in the southern hemisphere will meet with an adequate response, and that it will be devoted there to this all-important work.

ELECTRICAL NOTES.

An electrolysis problem which seems likely to attract attention has arisen in recent years in New Bedford. The city receives its water through a 48-inch steel force main, which has been damaged by the return currents of the Old Colony Street Railway for several years, and evidences of marked deterioration have been frequently detected. The attention of the railway company has been called to this continued destruction by the board of water commissioners, and after long delay the company bonded its tracks in the vicinity of the main and put an insulating joint in a service pipe running from it which was carrying a large amount of current. Mr. William E. Foss, who has investigated many electrolytic conditions in Boston and vicinity, was engaged to report on the protective measures taken in New Bedford, and as a result of his investigations he states that the bonding of the track and the use of an insulated joint were of no service. In his opinion the only remedy will be the introduction of a double trolley on this road, which he does not regard as a serious burden in view of the nature of the traffic. Inasmuch as the city depends for its water supply on this force main, and its destruction by electrolysis seems very likely, the National Board of Fire Underwriters has taken up the matter and urged energetic and drastic action against the railroad company to compel it to keep its return currents off the main. Inasmuch as fire underwriters generally succeed in the course of time in accomplishing their purpose, it seems likely that the Old Colony Street Railway Company will shortly find itself facing a pretty serious situation. Any failure of the New Bedford water supply due to electrolysis would arouse public condemnation in a manner likely to be remembered.—Engineering Record.

An electro-plating method which appears to be somewhat novel has been brought out in France. It comes into use especially where the object to be plated is of large size and it would be inconvenient or expensive to use a large plating tank. Besides, the method allows of plating a single object with different kinds of metal in different parts, and in this way some varied and unique effects can be produced. While not intended to supersede the usual methods, it may serve to replace or complete them in certain cases. Besides it is quite easy to operate by anyone having a source of current. A simple brush contains the electroplating liquid. A wire is wound around the upper end of the bristles so as to give a good contact, and this wire is connected to the positive pole of the circuit. The negative wire is connected with the object to be plated, and by simply brushing the solution upon the object we obtain a regular and adherent deposit. Naturally, the object is to be well cleaned, as usual. The thickness of the layer which is formed depends upon the time employed in the brushing and the number of times which the brush is passed over a part already coated. The method which gave the best results upon trial was the following: Using a circuit of 110 volts, such as the usual city mains, we use a resistance formed of six 50-candle-power lamps connected in series and representing a total of 750 ohms. The brush and the object are connected in the circuit which is thus formed, and only a small current is actually used. Such a process may render some service in different cases. Large metal objects can be covered and thus protected from the air. One interesting use is in plating objects with different metals, thus giving a polychrome metallic decoration. The layer of metal is thin, and in some cases is best covered with a protecting varnish. Any of the usual plating baths can be used.

ENGINEERING NOTES.

The work of piercing the five-and-a-half-mile tunnel through the Tauern Mountains in Tyrol, a few miles south of Gastein, has been completed. The enterprise has occupied six years, and it is the last important work in the completion of Alpine railways. The new tunnel will shorten the journey between Salzburg and Trieste by 110 miles.

The engineering experiment station of the University of Illinois has issued a bulletin on "The Effect of Scale on the Transmission of Heat Through Locomotive Boiler Tubes," by Edward C. Schmidt, M.E., and John M. Snodgrass, B.S. This bulletin describes a series of experiments begun in 1900 by the railway engineering department of the University of Illinois to determine the relation of the heat loss due to scale to the scale thickness. The experiments comprise tests on single tubes as well as tests of the entire locomotive boiler. The results of all the tests, plotted with reference to scale thickness, show great divergence in the heat loss, which is ascribed to differences in scale structure. It shows: (1) That for scale of thicknesses up to 1/8 inch, the heat loss may vary in individual cases from insignificant amounts to as much as 10 or 12 per cent. (2) That the heat loss does increase with thickness in an undetermined ratio. (3) That mechanical structure of the scale is of as much or more importance than thickness in producing this loss. (4) That chemical composition, except in so far as it affects the structure of the scale, has no direct influence on heat transmission.

Panama Canal progress for June, 1907, is reported as follows: Excavation in Culebra Division, 624,600 cubic yards, all from canal prism proper (as compared with 669,400 cubic yards for May, 1907, and 207,800 cubic yards for June, 1906); average per shovel, about 16,000 cubic yards. The rainfall during the month, distributed over 24 days, was 13.3 inches, about twice as much as for June, 1906. Excavation at Gatun, 75,000 cubic yards. Dredging in canal prism, 81,400 cubic yards. Locomotives in service, 141; 62 miles of new track were laid and 3½ miles of old track were removed. The total working force, exclusive of employees of the Panama Railroad, was 23,327. The Sanitary Department, covering both the commission forces and the railroad forces, reports 91 deaths. Of these 72 were among the 29,000 colored employees, 4 among 4,300 American whites, and 15 among 6,500 whites other than Americans. This is a decrease from the 96 deaths reported for May. There is a similar decrease in the deaths from pneumonia (30 against 33) and typhoid fever (8 against 13). There were no typhoid deaths among the white employees. There were no deaths whatever among the 1,200 white women and children living in commission quarters in the zone.

Considerable progress is being made in standardizing the specifications and contour of rails for steam railroad service. At its meeting in Atlantic City, June 20-22, the American Society of Testing Materials voted to adopt, subject to a letter ballot, the standard specifications for steel rails which it has had under consideration for some time, though making no radical change in their wording. This action has been followed by the more or less definite rumor that the new Pennsylvania specifications include the cropping of the ingot 25 per cent, instead of the much smaller percentage now general, and to be otherwise so rigorous that they will increase the price of rails some $5 a ton. No rails, however, have been purchased under these specifications, and it is quite probable that when made public they will be found not to agree with the somewhat vague estimates which have been made of their terms. During the debate on the subject of rails which has been so rife during the past year or so, many claims have been made that it would be better to substitute open-hearth for Bessemer steel, as the former is considered better on account of its lower percentage of phosphorus. On the other hand, certain experts claim that immunity from breakage in rails is not so much a question of such slight differences in composition as would be secured by changing to the open-hearth process, or freedom from piping as would be gained by cropping the ingot, as it is of speed in rolling. According to this theory, it is claimed that with the present heavy A. S. C. E. sections, it is very difficult to roll these heavy sections without finishing them at too high a temperature. In the meantime, the selection of a new standard section of T-rail is being discussed by the experts of the railroads and rail mills, but final decision on this subject is being withheld pending the report of the rail committee of the American Society of Civil Engineers. This committee was appointed in 1902, when it was found that the present A. S. C. E. standards needed modification. It is understood, however, that the Pennsylvania specifications referred to above take up the question of section of rail as well as its manufacture, so that there are really two independent bodies of engineers working upon this question. Fortunately, the subject is not so pressing with street railway companies, and they can well wait until the matter reaches a more definite stage with the steam railroad companies.—Street Railway Journal.

TRADE NOTES AND FORMULÆ.

Graphite Packing for Steam Pipes.—Linen cottonade, paper, etc., is treated with 1 part of paraffine, 0.04 part of rubber, 0.75 part of white lead, 0.8 of zinc white, 0.8 part of graphite, and 0.8 part of wood shavings.

Covering for Steam Pipes, etc.—225 parts of water, 20 parts of potter's clay, 39 parts of fossil meal (infusorial earth), 7 parts of horse or cow hair, 3.5 parts linseed oil, 3.5 parts of sifted rye flour, 2.5 parts of beet sugar molasses (ultimately, if desired, also 3.5 parts of flaxseed meal).

Fireproof Roofing Paper, Not Brittle.—Ordinary impregnating tar is boiled with water-glass solution, ordinary roll pasteboard is drawn through the mixture and sprinkled with the finest possible sand. If in place of cardboard jute fabric is used, which it is best to pass first through a bath of water-glass, the roof covering will not be brittle.

Varnish for Gold Moldings.—

a. Seed lac 2, mastic 2, gamboge 1, alcohol 14.

b. Seed lac 2, shellac 2, gamboge 6, saffron 1, annatto 2, alcohol 15.

c. Seed lac 2, sandarac 4, elemi 4, gamboge 2, dragon's blood 2, turmeric 1, alcohol 45.

d. Shellac 4, sandarac 4, mastic 2, Venice turpentine 5, rosin 1, dragon's blood 4, gamboge 4, alcohol 70.

e. Shellac 1.5 parts by weight in alcohol 30 parts, mastic 2.5 in alcohol 5 parts, sandarac 1.5 parts in alcohol 5 parts, gamboge 2.5 parts in alcohol 5 parts, turpentine 1.5 parts in alcohol 5 parts, 1.5 parts of sanders extracted with 5 parts of alcohol. The ingredients to be dissolved separately, filtered and mixed.

Other Receipts for Varnish for Gold Moldings.—

a. Amber 25, dragon's blood 20, gamboge 25, seed lac 100, saffron 1, sanders 3, alcohol 500.

b. Shellac 1.2 parts, sandarac 0.5 part, gamboge 0.25 part, red sanders 0.2 part, Venice turpentine 0.15 part, 5 parts of alcohol of 95 per cent. The sanders is first extracted with a part of the alcohol.

Matt Varnish for Imitation Gold Moldings.—Pale shellac 0.25 part, absolute alcohol 2 parts, chalk 0.25 part.

Varnish for Imitation Gold Moldings.—Sandarac 10, elemi 1, mastic 1, alcohol 20.

Nutritive Powder for Cattle.—

a. Fœnum græcum 4, linseed 4, juniper berries 4, rosin 4, mustard 4, Glauber's salt 3, common salt 3, flowers of sulphur 3, green vitriol 3, black antimony 1, Chili saltpeter 1, coriander 1.

b. Sulphide of antimony 4, flowers of sulphur 4, bean or malt flour 225. Dosis: 1 tablespoonful in the feed.

c. Flowers of sulphur 2, fenugreek seed 4, tartar 1, licorice 1, Chili saltpeter 1, sulphide of antimony 0.5, gentian 0.25, aniseseed 0.25, common salt 1. Dosis: 1 ounce daily for two to three weeks.

d. Gentian 4, licorice 4, fenugreek 16, saltpeter 4, common salt 4.

e. Aromatic powder 2, asafœtida 0.25, tartar 0.75, sulphide of antimony 0.5.

f. Sulphide of antimony 10, flowers of sulphur 9, elm bark 4, rosin 2, Chili saltpeter 2, aniseseed 1. Dosis: Heaped tablespoonful once or twice a day.

g. Anhydrous green vitriol 5, cantharides 1, ginger 3, sulphide of antimony 6, Chili saltpeter 5, flowers of sulphur 10, linseed 10, gentian 7, tartar 3, rosin 5, aniseseed 5. Dosis: One tablespoonful once or twice a day in the feed, or mixed with molasses, honey, or glycerine in one mass, which is given in a capsule of gum.

h. Tartar 5, flowers of sulphur 5, rosin 5, guaiacum 3, Chili saltpeter 2, gentian 5, golden sulphur 6.

j. Gentian 100, fenugreek 50, fennel 50, cattle salt 300, bicarbonate of soda 100, Glauber's salt 400, saltpeter 50, juniper berries 400.

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